US Army Corps of Engineers
Waterways Experiment Station

Miscellaneous Paper CERC-93-6
August 1993

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Coastal Research Program

DYNLET1 Application to Federal Highway Administration Projects

compiled by Mary A. Cialone, H. Lee Butler
Coastal Engineering Research Center

Michael Amein
Civil Analysis Group, Inc.

Approved For Public Release; Distribution Is Unlimited

Prepared for Federal Highway Administration

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Atlanta, GA 30367

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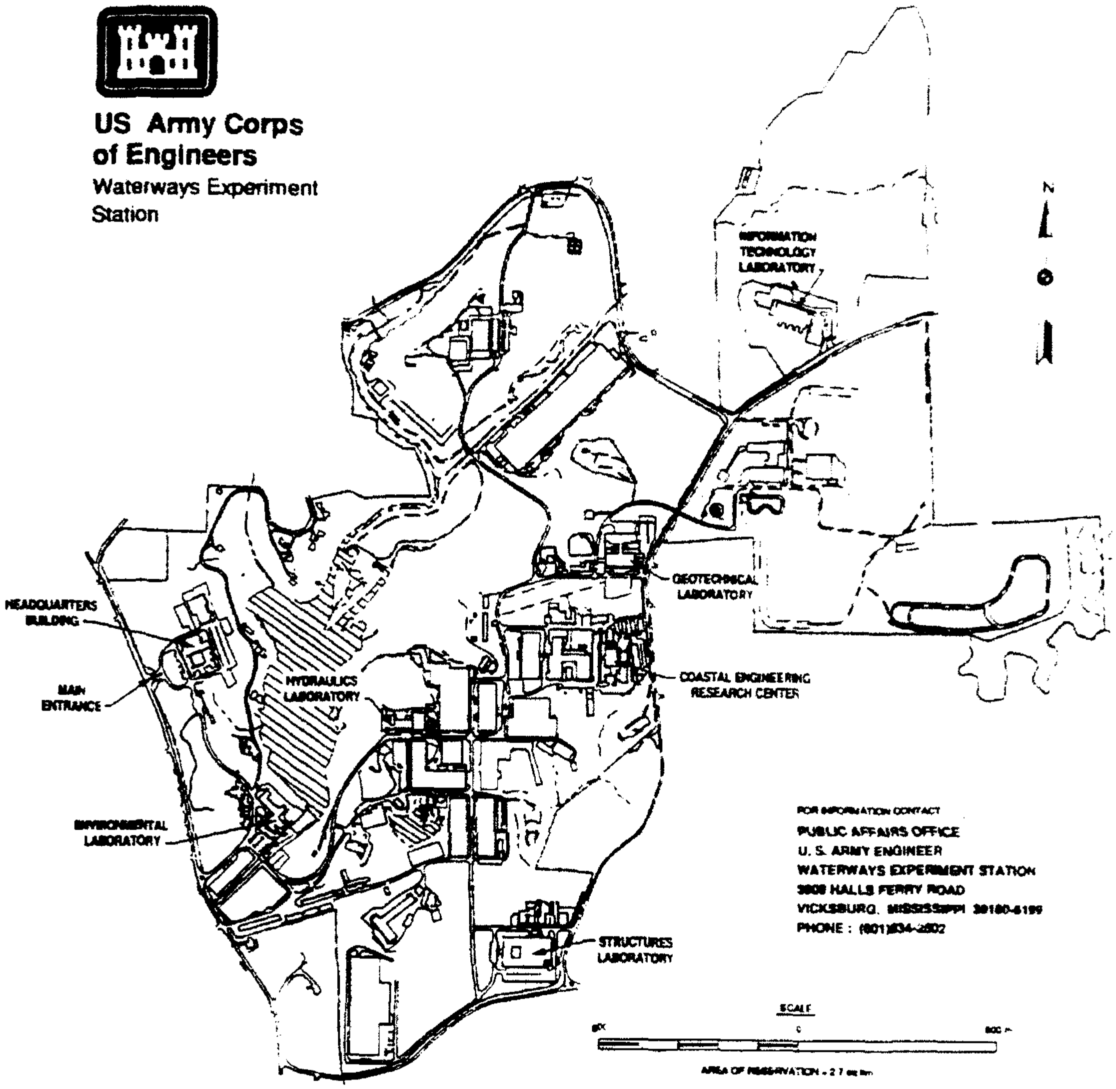

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Preface

The DYNLET1 numerical model was originally developed by Dr. Michael Amein, Civil Analysis Group, Inc., Raleigh, North Carolina, under contract to the U.S. Army Engineer Waterways Experiment Station (WES) Coastal Engineering Research Center (CERC). The model is capable of simulating one-dimensional (1-D) fluid flow from the ocean through a tidal inlet, to back-bay regions, and up tributaries. An important feature of the model is the ability to accurately represent flow distribution across any cross section, given the inherent limitations of a 1-D model.

The purpose of this study, sponsored by the U.S. Department of Transportation (DOT), is to document the current model version with specific emphasis on DOT needs and to apply the model to DOT-selected example project sites. A companion report prepared for the DOT covers model theory and documentation. This report focuses on application procedures and examples. Of primary interest to the DOT is the development of a statistical approach for estimating return periods of velocities impacting bridge piers at project sites. DYNLET1 is used to compute the storm-induced velocities. Knowledge of storm-induced velocities will improve estimation of potential scour at bridge piers.

The statistical approach used in this study was developed by Dr. Norman W. Scheffner, Research Hydraulic Engineer, Oceanography Branch, CERC, and his outstanding effort is acknowledged. This work was performed under the direct supervision of Mr. Bruce A. Ebersole, Chief, Coastal Processes Branch, and Mr. H. Lee Butler, Chief, Research Division, and under the general supervision of Dr. James R. Houston and Mr. Charles C. Calhoun, Jr., Director and Assistant Director, respectively, CERC. At the time of publication of this report, Dr. Robert W. Whalin was Director of WES. COL Bruce K. Howard, EN, was Commander.

Conversion Factors, Non-SI To SI Units Of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
knots	0.5144444	meters per second
nautical miles	1.8532	kilometers

1 Introduction

Model DYNLET1 is a one-dimensional (1-D), shallow-water equation, hydrodynamic model for predicting velocities and water level fluctuations in a system of inlets and bays (Amein and Kraus 1991, 1992). The objective of this report is to describe the process of applying DYNLET1 to a tidal inlet, specifically to Brunswick Harbor, Georgia, for the purpose of estimating tide and storm response at U.S. Department of Transportation (DOT) project sites. A second inlet, Charleston Harbor, South Carolina, will be used for hands-on training in model application at a DOT sponsored workshop. Limited documentation of the second application is also presented in this report. Model theory and a user's guide were described in a companion report (Cialone and Amein 1993).

The process of model application involves several steps including data acquisition, grid development, model validation, and storm application. In this report, data requirements for model validation as well as for storm simulations are presented. The details of grid development are given in a companion report (Cialone and Amein 1993). Typically, DYNLET1 is tidally-calibrated with field data to a specific project site. However, if historical storm surge data are available, a storm calibration is performed. Once calibrated, DYNLET1 is used to simulate the hydrodynamic response of the system to storm events. Storm hydrographs are used as input to DYNLET1 and model results are saved at critical locations (i.e., near a bridge pier). Velocities produced by the model are thus used to construct velocity-frequency curves for a specific area. This report covers the entire application process.

A primary DOT goal is to develop methodology for estimating frequency-indexed currents impacting bridges. DYNLET1 is an excellent model for computing storm currents precisely at bridge piers, however, a statistical procedure is needed to select what events to simulate and how the results should be analyzed to yield frequency of occurrence of storm-induced velocities.

Chapter 2 of the report discusses the process of tidal simulation and model calibration. A simplified statistical procedure for storm selection is presented in Chapter 3 and analysis methods for the resulting data are reported in Chapter 4. Chapters 5 and 6 cover application of DYNLET1 and statistical

procedures to Brunswick and Charleston Harbors, respectively. Chapter 7 discusses an analysis for multi-inlet systems. Appendices A through D present auxiliary codes, data files, and model results.

2 Tide Simulation

Background

Before using a numerical model as a project design tool, it must be calibrated with field data to ensure that the model variables are properly "tuned" to a specific project site. A model that can properly simulate hydrodynamics at a given site during one time period (preferably two time periods with varying conditions) can then be confidently used to predict flow conditions during other time periods. The major steps in a hydrodynamic model simulation of a tidal inlet are:

a. Acquiring data for use in model calibration and validation.

b. Developing a grid network which represents the inlet system.

c. Digitizing cross-section bathymetry, and obtaining boundary condition time series and other required model input data.

d. Calibrating the model to measured data by adjusting parameters such as local friction or channel transition loss coefficients.

e. Validating the model by assessing model performance against other known data sets.

f. Applying the model to assist project engineering.

This section briefly discusses some of the elements in this process.

Data Requirements

The primary data required for model application are bathymetric data and boundary forcing data. In addition, velocity and/or water level data at sites within the inlet/back bay system are needed for comparison to model results. Bathymetry data (on bathymetric charts) can be obtained from the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), or from a local U.S. Army Corps of Engineers (COE)

District. Boundary condition specifications are an integral part of the input data set. Generally, they consist of tidal elevation forcing just outside the inlet entrance and river discharge information for other external (river) boundaries of the system. These data may be available from the same three agencies mentioned above. Field data collection efforts to obtain tide and current response in various inlet/back bay systems have been conducted from time to time by state and Federal agencies. Inquiries should be made to determine the existence of data sets pertinent to a study site.

Current data are extremely useful in validating a model application. Data for examples given in this report were obtained from the Federal Highway Administration and COE studies. Similar data may be obtained from the local COE District, NOAA, USGS, or from the U.S. Army Engineer Waterways Experiment Station (WES) which has conducted a large number of physical and numerical model studies, publishing useful data in project technical reports. In lieu of specific data for a project site, NOAA Current Tables (U.S. Department of Commerce 1986) may provide useful information on peak current speeds. As a example, Figure 1 gives current predictions for Charleston Harbor during September and October 1987.

Calibration

The process of model calibration involves applying the model for a period of time when measured data are available to assess how well the results are replicating flow characteristics of the system. At a minimum, it is important to accurately represent the head loss which occurs across a typical inlet. This requires time series data for water elevation on the open coast and in the back bay. Synoptic measurements of time series of current data at specific locations in the inlet or back-bay channels, especially at locations near the bridge site of interest, are extremely useful in obtaining a good model calibration.

For a typical tidal calibration simulation, the model is driven with measured tide or velocity data at the ocean boundary and the water surface fluctuation and/or velocity model response is compared to measured data at one or more locations in the system. Certain parameters can then be adjusted, over a realistic range, until a satisfactory comparison is reached. Key parameters which the engineer must select are friction (represented by a Manning's n) and transition loss coefficients (given by K_e, an empirical form-drag coefficient). Of course, it is very important to have the inlet and back bay geometries accurately represented with a grid network and cross-section data. Assuming the system geometry is correct, initial values for n range between 0.02 and 0.04 and 0.4 to 0.6 for K_e. Increasing n represents higher friction due to coarser bottom sand, vegetation, or other flow restriction, and increasing K_e represents a greater rate of energy loss due to flow expansion or contraction. This coefficient, as well as Manning's n, may be needed to fine tune the velocity calibration for flow through sharp channel constrictions, past bridge

86 CHARLESTON HARBOR (off Ft. Sumter), SOUTH CAROLINA, 1987

F-Flood, Dir. 335° True E-Ebb, Dir. 120° True

SEPTEMBER

Day	Slack Water Time h.m.	Maximum Current Time h.m.	Maximum Current Vel. knots
1	0110	0440	2.0E
Tu	0757	1051	2.0F
	1419	1730	2.0E
	2108	2326	1.3F
2	0223	0545	1.9E
W	0906	1158	2.0F
	1535	1842	2.1E
	2220		
3		0034	1.4F
Th	0344	0657	2.0E
	1017	1307	2.1F
	1647	1956	2.3E
	2325		
4		0149	1.5F
F	0459	0809	2.3E
	1124	1417	2.4F
	1751	2100	2.6E
5	0023	0254	1.8F
Sa	0605	0913	2.6E
	1226	1519	2.6F
	1848	2156	2.9E
6	0114	0355	2.2F
Su	0702	1010	2.9E
	1322	1617	2.8F
	1939	2247	3.1E
7	0202	0446	2.5F
M	0755	1102	3.1E
	1415	1707	2.9F
	2027	2333	3.2E
8	0247	0531	2.7F
Tu	0844	1152	3.2E
	1506	1753	2.9F
	2113		
9		0017	3.2E
W	0331	0616	2.7F
	0932	1238	3.2E
	1555	1837	2.7F
	2157		
10		0059	3.0E
Th	0414	0659	2.7F
	1019	1326	3.0E
	1644	1922	2.4F
	2239		
11		0141	2.8E
F	0458	0741	2.5F
	1106	1410	2.7E
	1734	2003	2.0F
	2323		
12		0226	2.5E
Sa	0543	0826	2.2F
	1155	1458	2.4E
	1826	2049	1.7F
13	0008	0311	2.1E
Su	0631	0912	1.9F
	1248	1552	2.1E
	1924	2138	1.3F
14	0058	0402	1.8E
M	0725	1003	1.6F
	1346	1655	1.8E
	2027	2234	1.0F
15	0156	0503	1.5E
Tu	0825	1102	1.4F
	1451	1804	1.6E
	2134	2343	0.8F

Day	Slack Water Time h.m.	Maximum Current Time h.m.	Maximum Current Vel. knots
16	0304	0614	1.4E
W	0930	1213	1.3F
	1556	1924	1.6E
	2239		
17		0127	0.8F
Th	0411	0729	1.4E
	1033	1340	1.3F
	1656	2025	1.7E
	2334		
18		0238	0.9F
F	0510	0827	1.6E
	1129	1441	1.4F
	1747	2110	1.9E
19	0020	0319	1.1F
Sa	0600	0916	1.8E
	1217	1519	1.6F
	1832	2151	2.0E
20	0059	0348	1.4F
Su	0643	0955	2.0E
	1301	1555	1.8F
	1911	2224	2.2E
21	0134	0411	1.6F
M	0720	1028	2.2E
	1340	1623	2.0F
	1946	2251	2.3E
22	0206	0438	1.8F
Tu	0755	1059	2.4E
	1417	1655	2.1F
	2018	2320	2.4E
23	0237	0510	2.0F
W	0828	1133	2.5E
	1454	1728	2.2F
	2049	2348	2.5E
24	0308	0544	2.2F
Th	0901	1208	2.6E
	1531	1805	2.2F
	2118		
25		0024	2.5E
F	0339	0622	2.4F
	0935	1247	2.7E
	1610	1844	2.1F
	2149		
26		0059	2.5E
Sa	0413	0703	2.4F
	1014	1328	2.6E
	1653	1925	2.0F
	2224		
27		0140	2.4E
Su	0452	0745	2.4F
	1058	1413	2.5E
	1742	2010	1.8F
	2304		
28		0227	2.2E
M	0537	0834	2.3F
	1150	1507	2.3E
	1838	2105	1.6F
	2354		
29		0320	2.1E
Tu	0633	0931	2.2F
	1253	1606	2.2E
	1945	2203	1.4F
30	0058	0421	1.9E
W	0739	1032	2.0F
	1406	1717	2.1E
	2056	2310	1.3F

OCTOBER

Day	Slack Water Time h.m.	Maximum Current Time h.m.	Maximum Current Vel. knots
1	0219	0535	1.9E
Th	0854	1142	2.0F
	1522	1831	2.2E
	2206		
2		0025	1.4F
F	0342	0650	2.0E
	1008	1255	2.1F
	1632	1945	2.4E
	2308		
3		0140	1.6F
Sa	0454	0803	2.3E
	1116	1409	2.2F
	1734	2046	2.6E
4	0003	0247	2.0F
Su	0555	0906	2.6E
	1216	1513	2.4F
	1829	2139	2.9E
5	0052	0342	2.3F
M	0650	1001	2.9E
	1311	1604	2.6F
	1918	2227	3.0E
6	0137	0427	2.6F
Tu	0739	1048	3.1E
	1402	1651	2.6F
	2004	2310	3.0E
7	0220	0511	2.7F
W	0826	1133	3.2E
	1450	1734	2.5F
	2047	2351	3.0E
8	0301	0550	2.7F
Th	0911	1219	3.1E
	1537	1815	2.3F
	2128		
9		0030	2.8E
F	0342	0631	2.6F
	0954	1300	2.9E
	1623	1854	2.1F
	2208		
10		0109	2.5E
Sa	0424	0709	2.4F
	1038	1343	2.6E
	1709	1932	1.8F
	2248		
11		0151	2.2E
Su	0506	0750	2.2F
	1123	1427	2.3E
	1759	2016	1.5F
	2329		
12		0232	1.9E
M	0552	0833	1.9F
	1211	1515	2.0E
	1852	2101	1.2F
13	0017	0322	1.6E
Tu	0645	0924	1.6F
	1305	1612	1.7E
	1951	2152	0.9F
14	0115	0419	1.4E
W	0744	1015	1.4F
	1407	1716	1.6E
	2055	2257	0.8F
15	0224	0528	1.3E
Th	0850	1123	1.2F
	1511	1829	1.5E
	2156		

Day	Slack Water Time h.m.	Maximum Current Time h.m.	Maximum Current Vel. knots
16		0010	0.8F
F	0332	0642	1.4E
	0955	1232	1.2F
	1611	1930	1.6E
	2249		
17		0123	1.0F
Sa	0433	0746	1.5E
	1052	1336	1.3F
	1703	2024	1.8E
	2335		
18		0212	1.2F
Su	0523	0833	1.8E
	1143	1428	1.5F
	1749	2103	2.0E
19	0015	0254	1.5F
M	0607	0916	2.0E
	1228	1509	1.7F
	1830	2134	2.2E
20	0051	0329	1.8F
Tu	0646	0955	2.3E
	1310	1545	1.9F
	1906	2208	2.3E
21	0125	0401	2.0F
W	0723	1030	2.5E
	1350	1622	2.0F
	1941	2243	2.4E
22	0158	0439	2.3F
Th	0759	1104	2.7E
	1429	1659	2.1F
	2014	2318	2.5E
23	0231	0515	2.5F
F	0836	1145	2.8E
	1509	1740	2.2F
	2047	2355	2.6E
24	0307	0556	2.6F
Sa	0915	1225	2.8E
	1552	1821	2.1F
	2123		
25		0036	2.5E
Su	0345	0639	2.7F
	0958	1310	2.8E
	1639	1906	2.0F
	2204		
26		0119	2.5E
M	0429	0726	2.6F
	1047	1400	2.6E
	1731	1954	1.8F
	2251		
27		0210	2.3E
Tu	0520	0819	2.5F
	1142	1456	2.5E
	1829	2051	1.6F
	2349		
28		0304	2.1E
W	0621	0914	2.3F
	1245	1557	2.3E
	1934	2152	1.5F
29	0059	0413	2.0E
Th	0730	1018	2.1F
	1355	1707	2.2E
	2041	2101	1.5F
30	0219	0526	2.0E
F	0845	1131	2.0F
	1507	1817	2.3E
	2146		
31		0016	1.6F
Sa	0335	0642	2.1E
	0957	1245	2.0F
	1613	1927	2.4E
	2245		

Figure 1. Predicted currents in Charleston Harbor for September and October, 1987 (U.S. Department of Commerce 1986)

piers, through culverts, and so forth. However, it requires high-quality field data for elevations and currents to achieve a well-calibrated model.

3 Storm Simulation

Background

As discussed in the DYNLET1 documentation (Cialone and Amein 1993), it is important to validate the models for tidal dynamics prior to project application. It is equally as important to check model representation of extreme events (if data are available). In most cases, the model domain will be small enough to ignore wind effects from a storm and simply drive the model at the ocean boundary with a time series of water elevation. However, if wind data are available and used, the model solution will be more accurate. The key data required to run storms on inlet grids or small inlet-bay systems are time series of water elevation. Historical storm surge data for a project site should be researched, acquired if available, and tested in the model for the purpose of model validation for surge events.

Hurricane wind and pressure fields can be represented and simulated by use of an empirical model which represents the storm with five parameters (Figure 2): (a) central pressure, (b) radius to maximum winds (R), (c) forward speed (f), and (d) track (described by travelling direction and landfall point). Central pressure is closely associated with the storm intensity whereas R and f are associated with extent and duration of impact at the shore.

This concept leads to a simple way to estimate the probability of exceedance of a water level or velocity at any particular point in the model domain. A more rigorous statistical method could be developed if a comprehensive frequency-indexed database of storm response was available at all coastal locations. This database is currently being develop by WES and the methodology for using it to estimate frequency-index storm response may replace the method described in this report.

Storm Selection

Storm data at most coastal locations are difficult to obtain. Three agencies are the best source for data: NOAA, the Federal Emergency Management Administration (FEMA), and the COE. FEMA has established flood frequency lines for the purpose of creating insurance guidelines. However, the

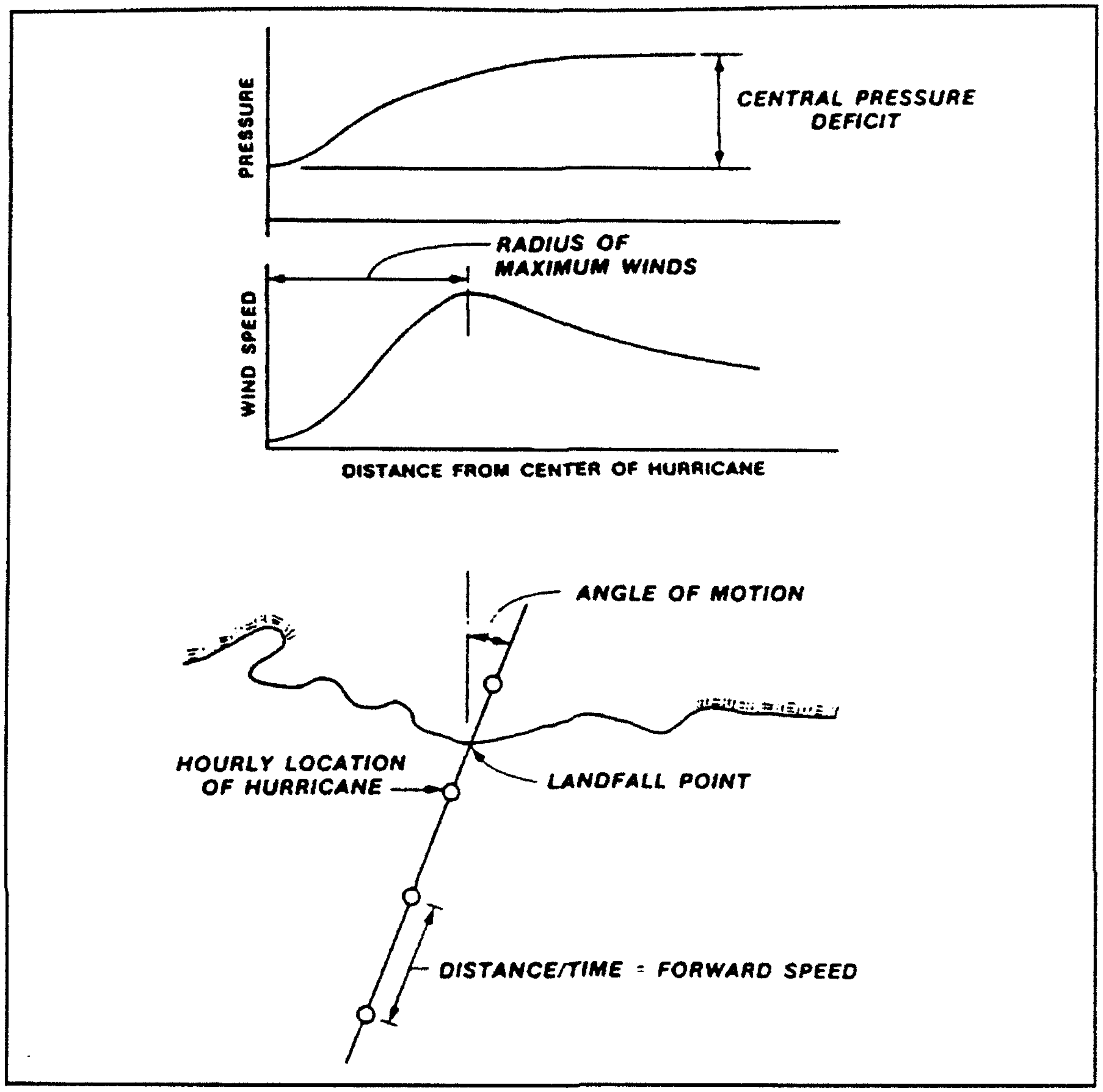

Figure 2. Schematic of hurricane parameters

open ocean stage-frequency curve or even stages for specific return periods may not be available. NOAA has conducted several site specific studies at various coastal locations but there is no general coverage of all U.S. coastlines. The local COE District or WES may be a source of data for DOT studies.

The following procedures require a minimum amount of data. Selection of storms to simulate for the purpose of estimating frequency-indexed velocities is based on knowing only surge-plus-tide stage at specific return periods. A given stage can be achieved by varying storm intensities, size (R), forward speed (f), track, and its combination with the tide. The objective is to develop a set of storm parameters $\{R, f\}$ which, when combined with tidal possibilities, form a total set of storm-tide events approximating the full spectrum of

conditions that may occur at a given site. Exceedance probabilities can then be attached to the computed velocities through a rank-order process. The initial step is to select values for R and f which represent maximum and minimum storm duration (D) by dividing estimates of maximum and minimum R by the minimum and maximum f, respectively.

$$D = 2R/f \tag{1}$$

Central pressure variation is accounted for in the way a particular surge hydrograph is convolved with tide. Let

$$S_{tot} = S_p + H_t \tag{2}$$

where S_{tot} is the peak total water elevation which is known from NOAA or FEMA data, S_p is the peak storm surge, and H_t is the known mean tide at one of four locations in the tidal cycle: mid-tide rising, high tide, mid-tide falling, and low tide. Rather than use a mixed tide, a single constituent is selected to represent tidal behavior at the inlet entrance. An auxiliary program (Chapter 4) uses a cosine function to simulate tidal elevation with the amplitude and period of a diurnal (24.84 hr) or semidiurnal (12.42 hr) constituent, depending on whether there is one or two high/low tides per day.

The pressure at a distance r from the storm center can be expressed as:

$$p_r = p_o + (p_n - p_o)e^{-(R/r)} \tag{3}$$

Since surge intensity varies with central pressure deficit, Equation 3 can be used to show the time evolution of surge height, represented by

$$S(t) = S_p(1 - e^{-(D/2t)}) \tag{4}$$

where $S(t)$ is surge level at time t. Two surge hydrographs for maximum and minimum durations are developed using Equation 4. Surge plus tide can be obtained by adding H_t and $S(t)$ at a specified phase of the tide, noting the peak value. The next step is to adjust S_p such that the maximum water elevation for a given combination is equal to the specified value S_{tot}. This procedure is equivalent to backing out a surge-only hydrograph which, when combined with a particular position in the tide, gives the known stage specified by NOAA/FEMA.

By running DYNLET1 for the two surge hydrographs combined with four tide positions gives eight storm-plus-tide events which produce the specified stage at a given return period. For each storm-tide combination, velocity at specified locations in the model are recorded for later statistical analysis. The range of velocities covers the range of possible storm-tide events. Exceedance probabilities can then be attached to the velocities through a rank-order process.

Data Requirements

To use the procedures discussed above, certain tide and storm data are required. Most of these data are readily available and, to a great extent, are presented in this report.

Tide data

Tide data on the open coast for all U.S. coastal locations are available in NOAA Tide Tables (U.S. Department of Commerce 1982). A 1982 publication is referenced, however these tables are published annually. The key data required are estimates of mean tide ranges which are given in U.S. Department of Commerce (1982) and rarely change from year to year. Figure 3 displays locations of primary reference stations where daily predictions of high and low water are available. Figure 4 shows the areal extent of tidal types for the east coast and Gulf of Mexico. For use with the above procedure, a mixed tide condition can be considered as a semidiurnal tide.

Storm data

NOAA has compiled data on nearly 1000 tropical storms covering a period of over 100 years. Figures 5-9 show storm tracks for tropical cyclones from 1886-1980. These curves give information on the frequency of landfalling or alongshore hurricanes and frequency of occurrence for given months and regions.

The most important data required in the procedure outlined above are estimates for characteristic parameters, R and f, which are associated with storm duration and extent of impact. NOAA published a comprehensive analysis (U.S. Department of Commerce 1975) of available storm data in 1975. Figures 10-12 display probability distributions of radius of maximum winds and forward speed (landfalling and alongshore). Results are identified with a given percentile of occurrence. These data can be used to develop the precise input for developing storm-tide combinations required by the storm model.

Model Validation for Storms

Data for model validation (elevations and/or currents) may be available from the local COE district, WES, FEMA. or NOAA. Prior to estimating frequency-indexed velocities, it is recommended to research and acquire any available data taken during a storm event. The same model parameters and coefficients used for tidal calibration are the starting values for storm

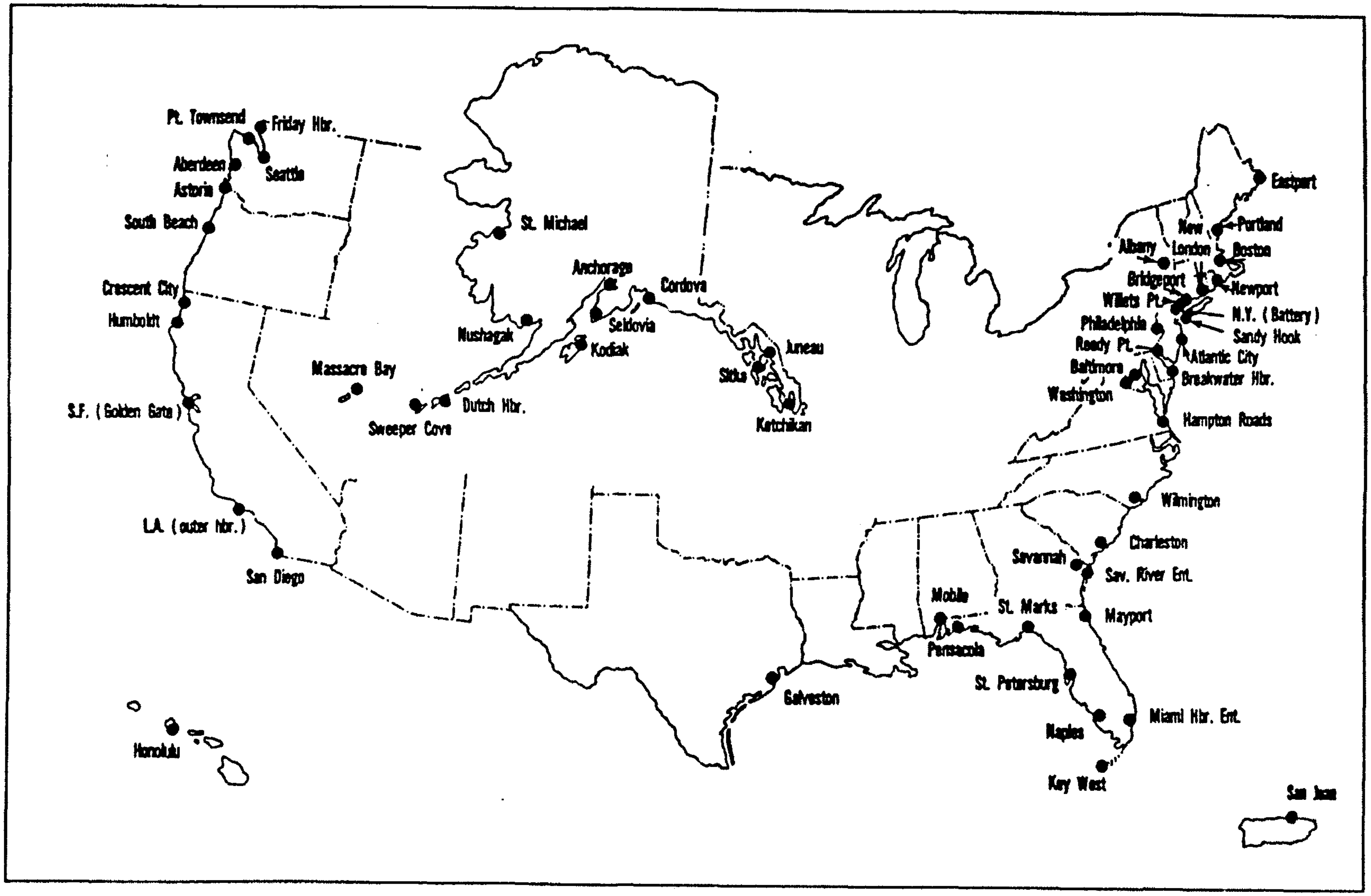

Figure 3. Location of reference and comparative tide stations: Atlantic, Gulf, and Pacific coasts

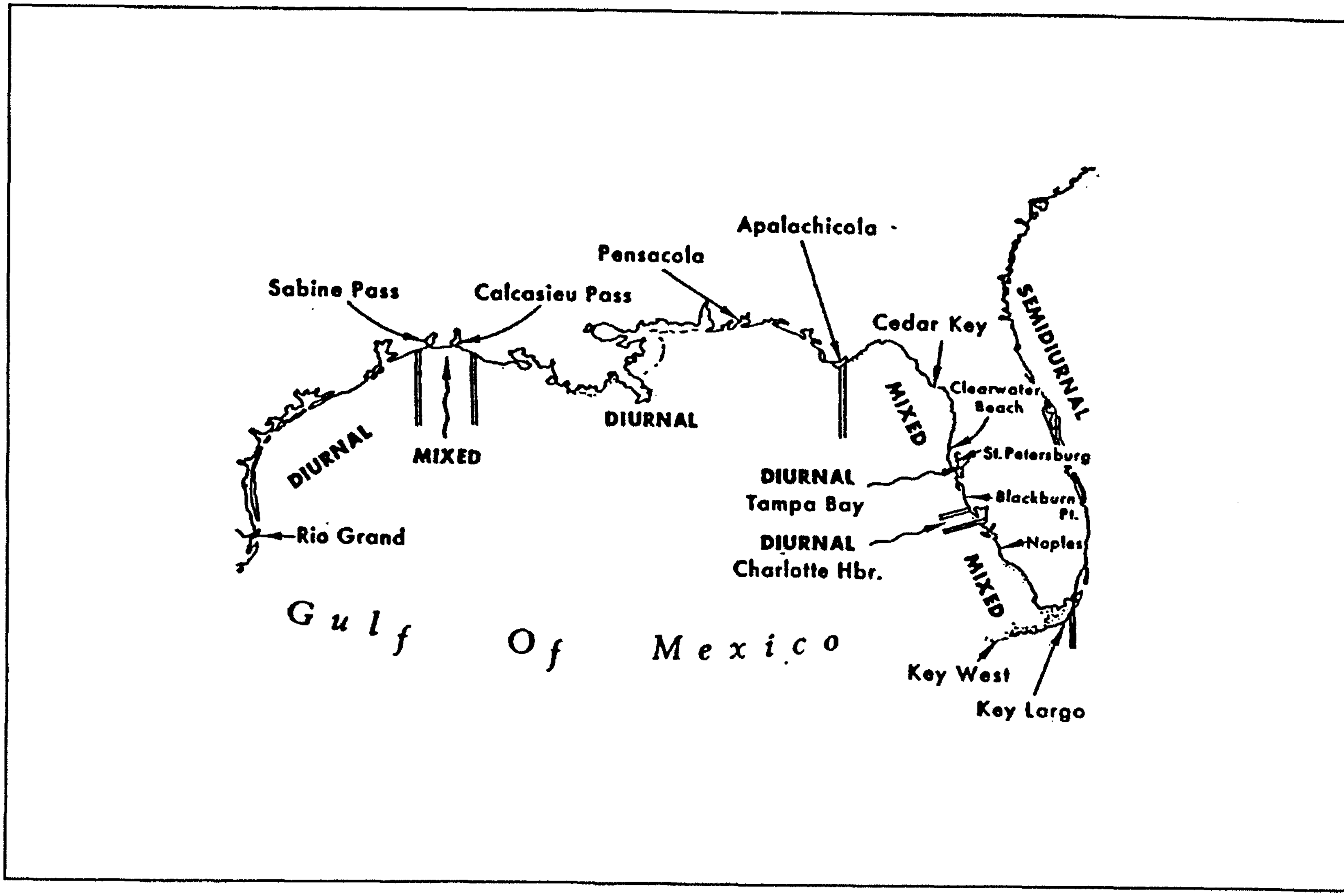

Figure 4. Areal extent of tidal types and locations of stations with illustrated tidal curves

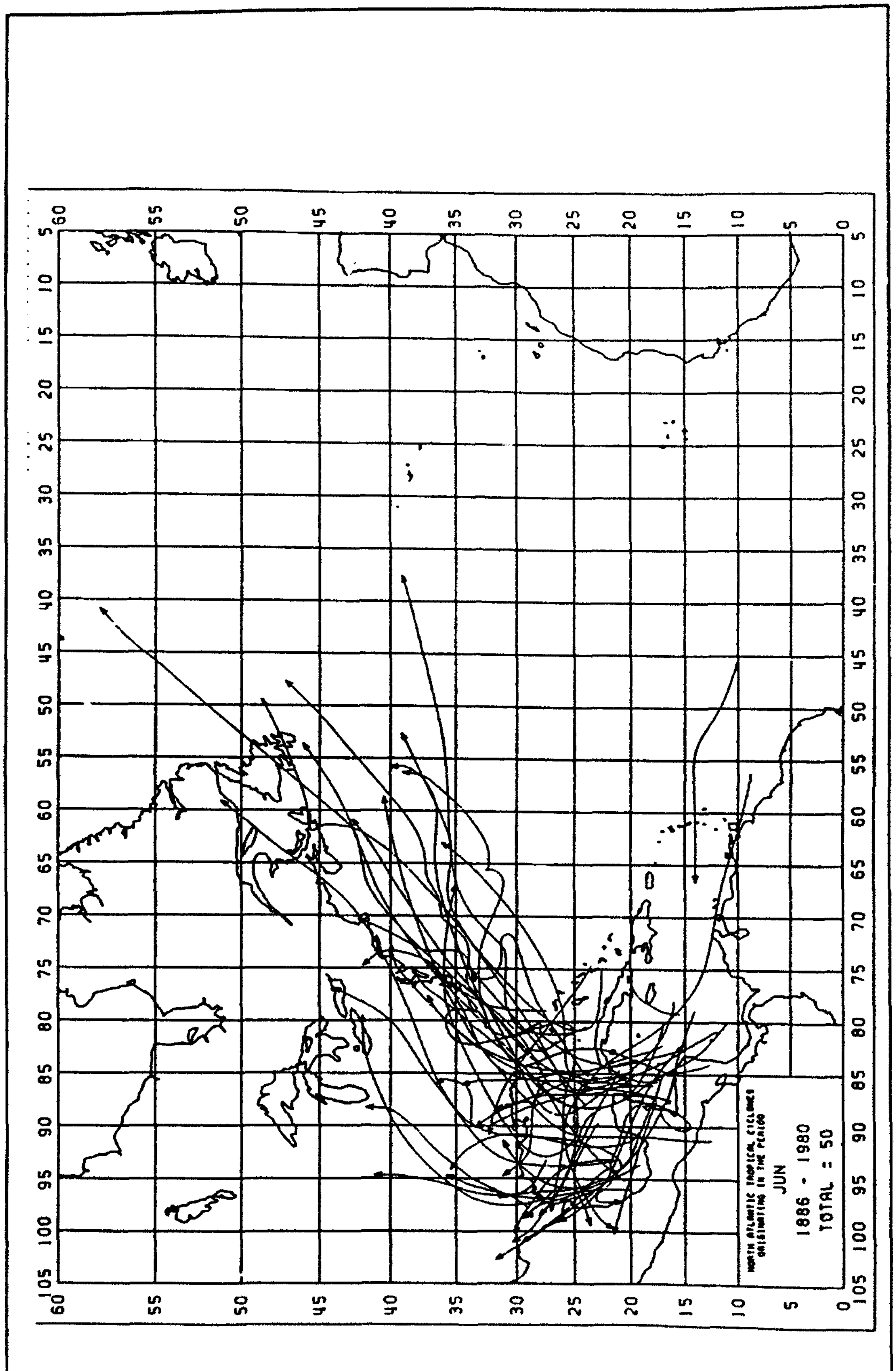

Figure 5. Paths of North Atlantic tropical storms (1886-1980) for June

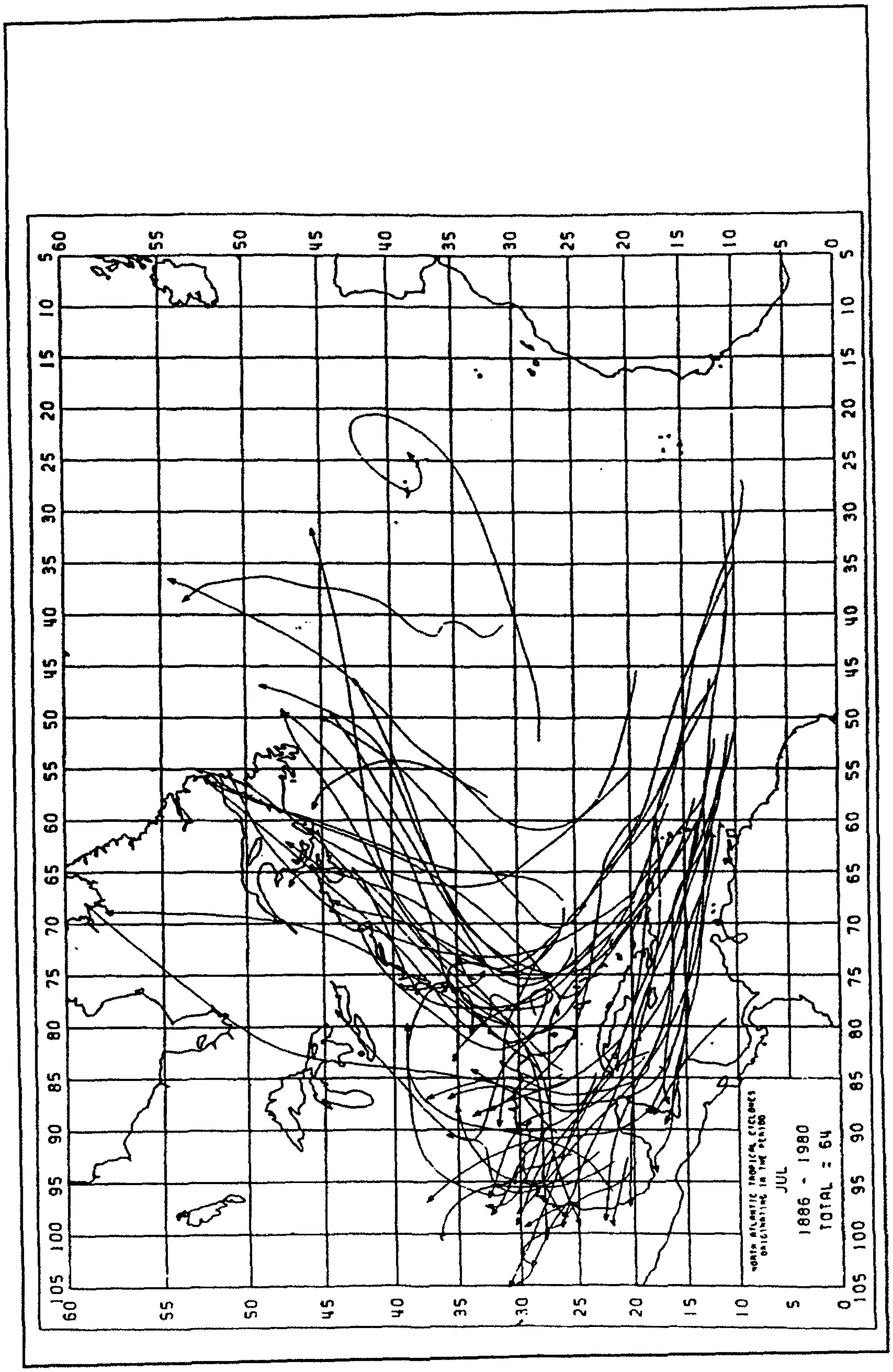

Figure 6. Paths of North Atlantic tropical storms (1886-1980) for July

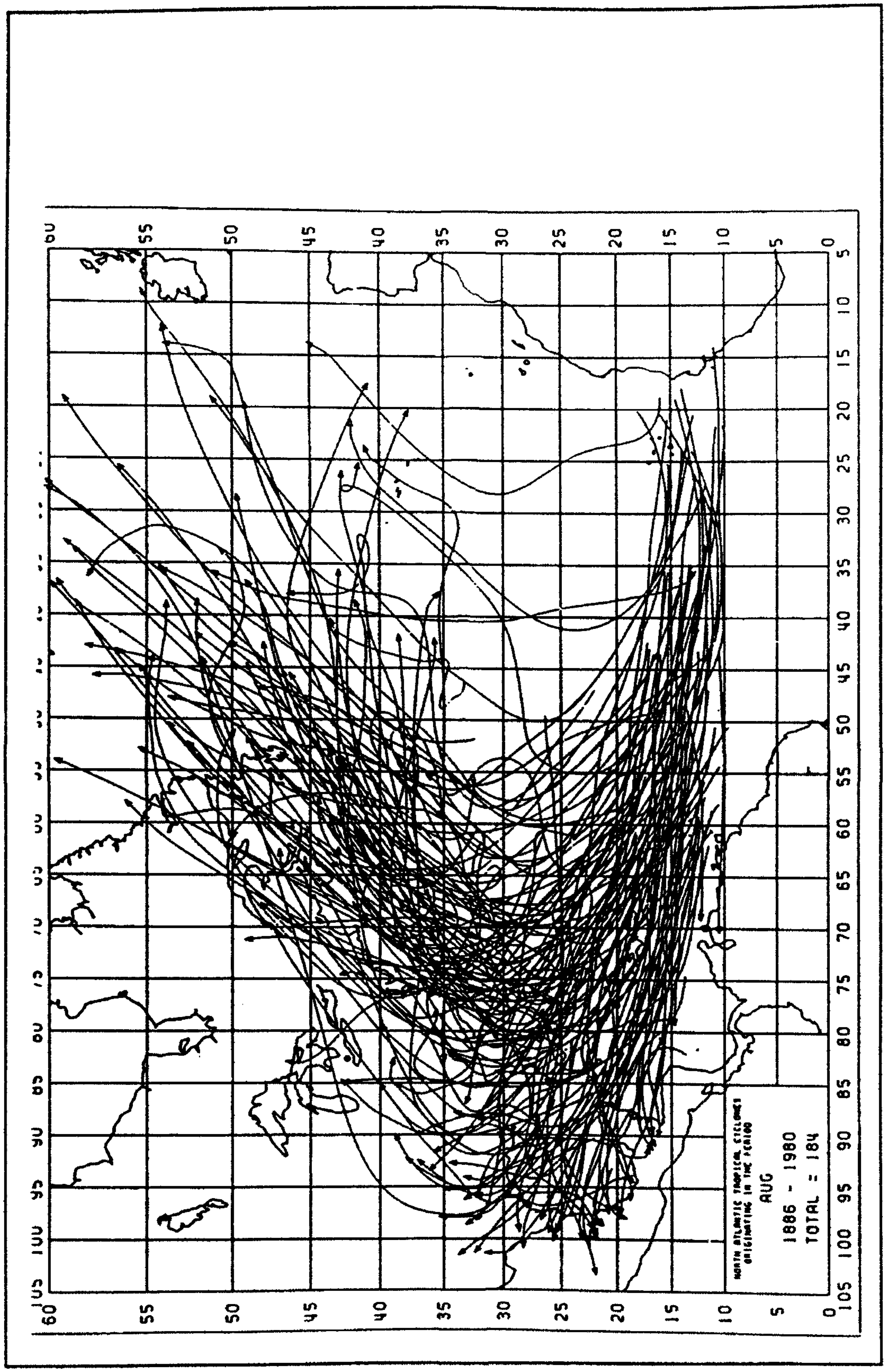

Figure 7. Paths of North Atlantic tropical storms (1886-1980) for August

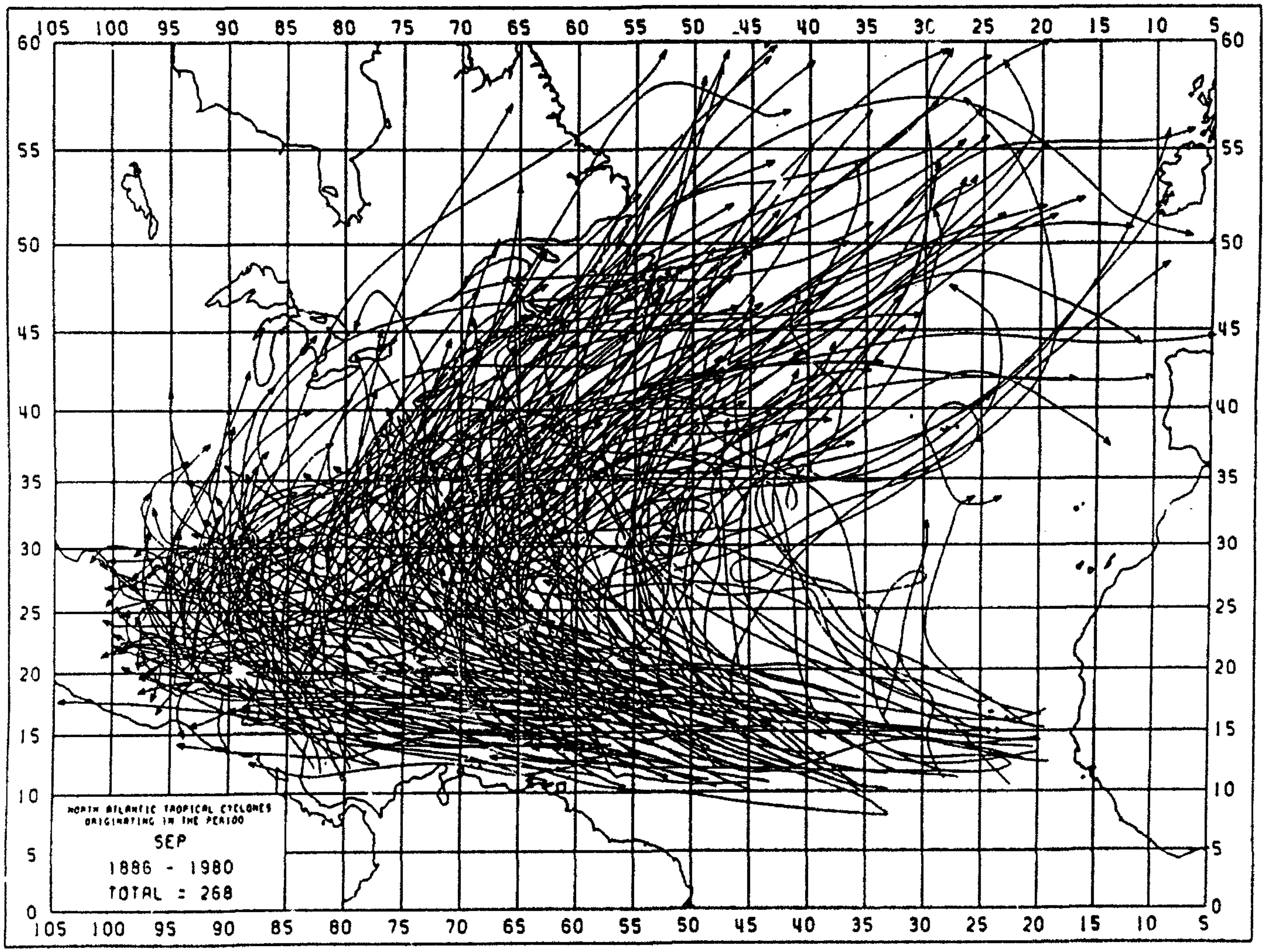

Figure 8. Paths of North Atlantic tropical storms (1886-1980) for September

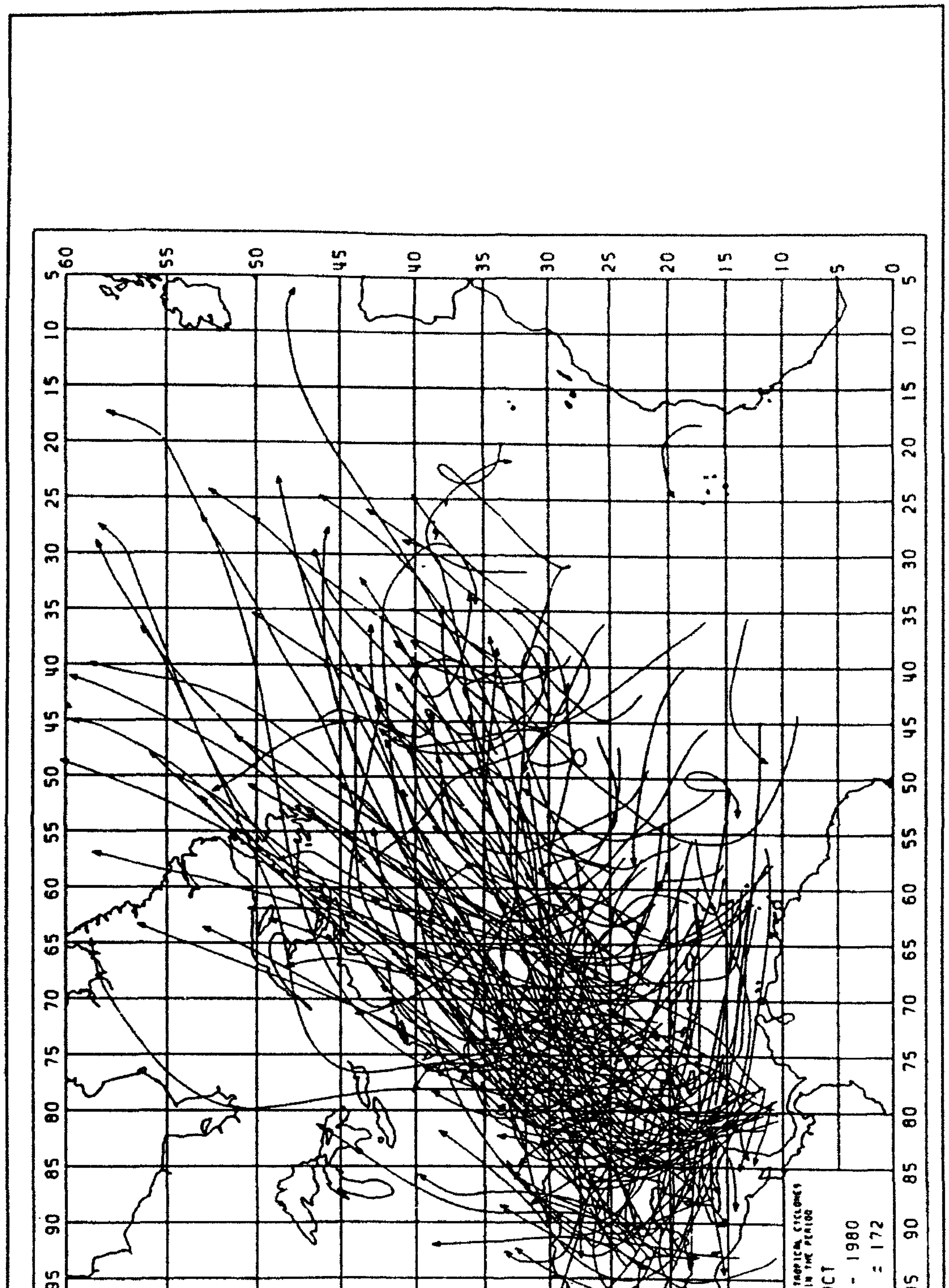

Figure 9. Paths of North Atlantic tropical storms (1886-1980) for October

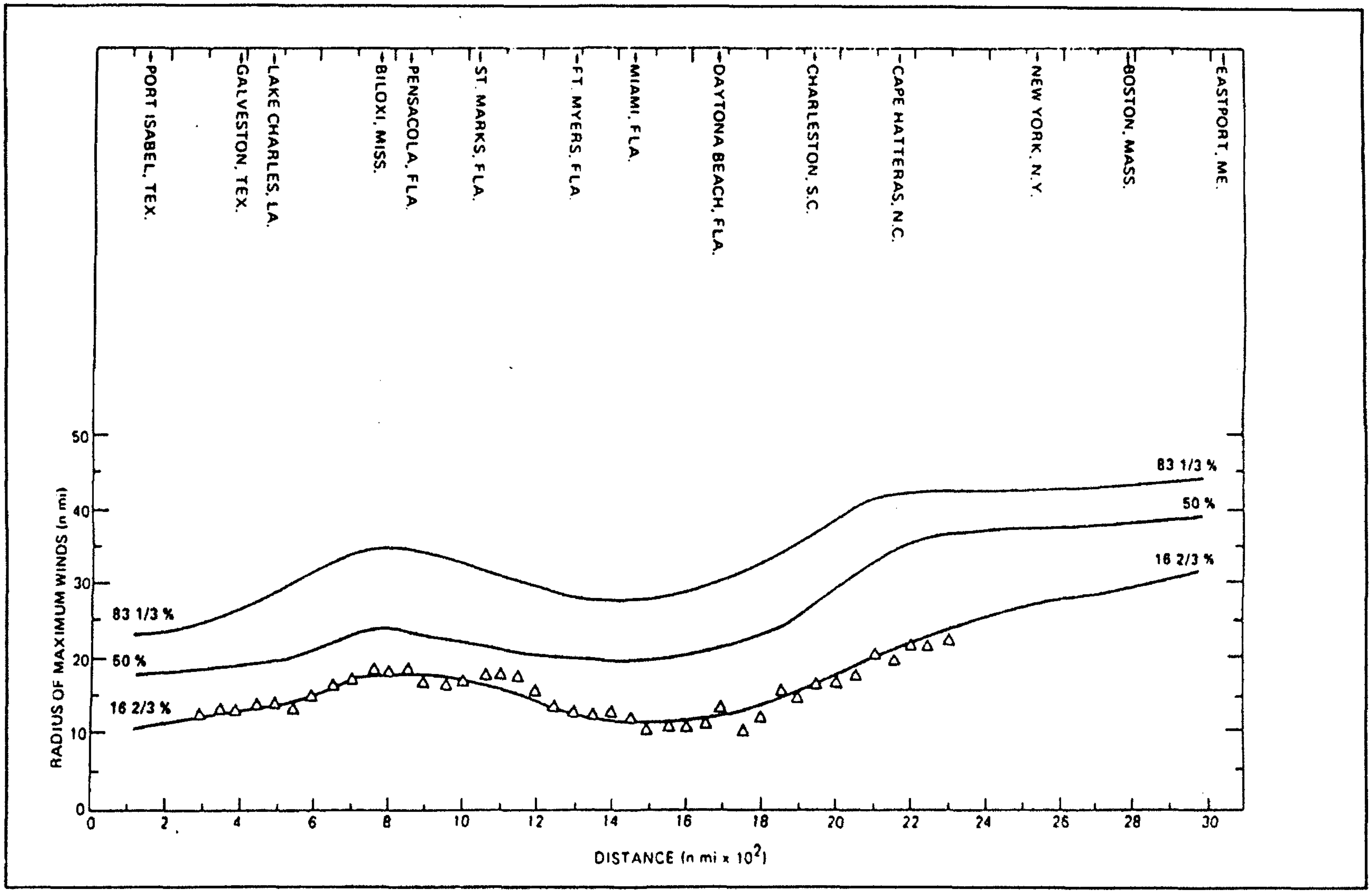

Figure 10. Probability distribution of radius of maximum winds of hurricanes, Gulf and east coasts (1900-73). Numbered lines denote the percent of storms with R equal to or less than the value indicated along the ordinate. Plotted points (Δ) are taken from the frequency analyses at 50-n.m. intervals for the 16-2/3 percentile

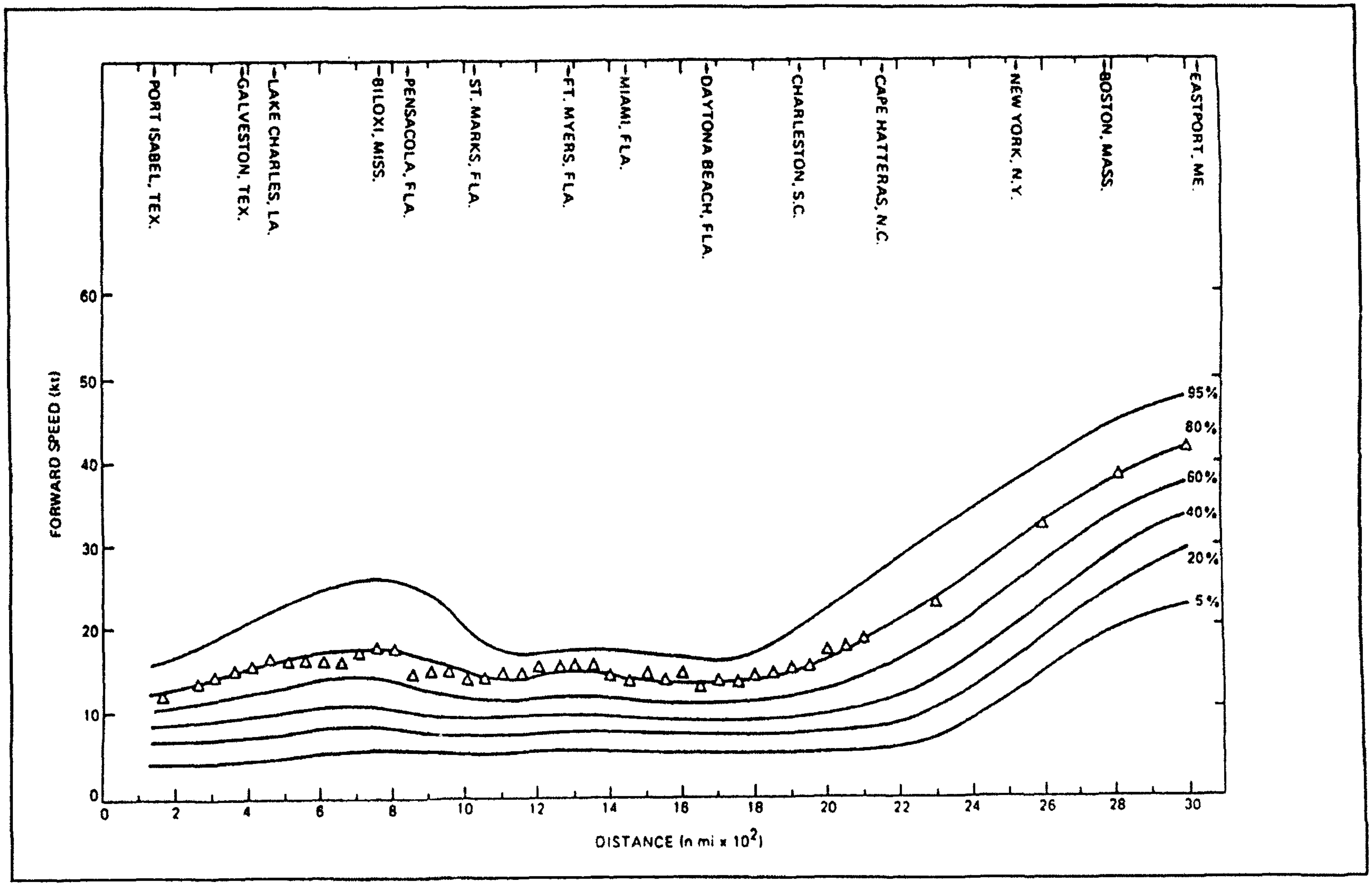

Figure 11. Probability distribution of forward speed for landfalling hurricanes, 1886-1973. Numbered lines denote the percent of storms with forward speed equal to or less than the value indicated along the ordinate. Plotted points (Δ) are taken from the frequency analyses at 50-n.m. intervals for the 80th percentile

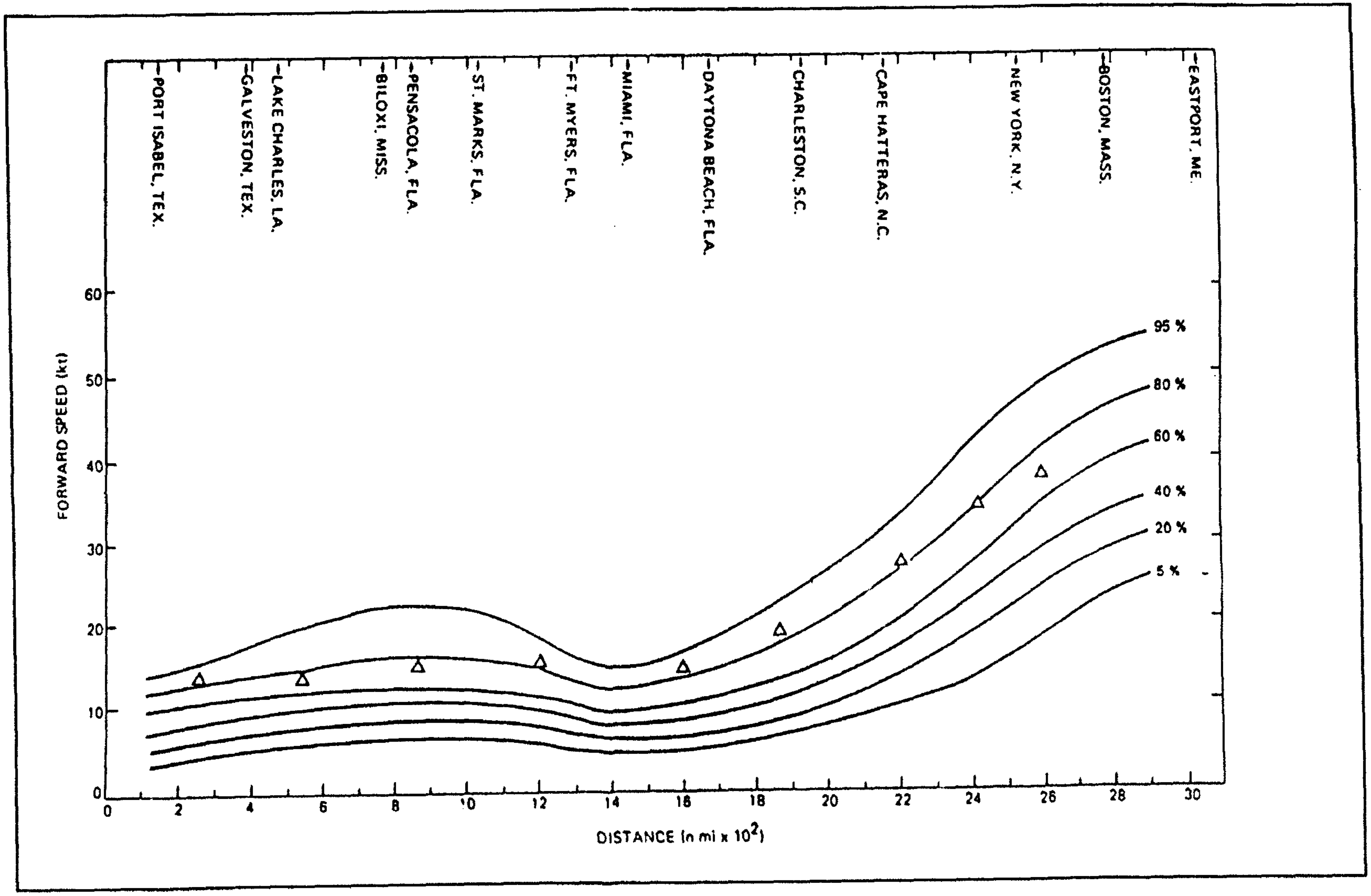

Figure 12. Probability distribution of forward speed for alongshore hurricanes, 1886-1973. Numbered lines denote the percent of storms with forward speed equal to or less than the value indicated along the ordinate. Plotted points (Δ) are taken from frequency analyses for the 80th percentile

validation. Generally, these values are appropriate for extreme events as well as typical tides.

Wind may play an important part in the simulation of storm impacts and should be used if available. It is wise to test the sensitivity of the results by running the model with and without wind forcing. In most cases (because the model domain is usually small in area and/or fetch lengths over open water are short), forcing the model at the ocean boundary with a measured storm hydrograph (which inherently contains wind effects) is sufficient to compute a valid elevation and velocity response in the model interior due to the storm. This, however, neglects local wind effects and their impact should be investigated during sensitivity testing.

Validation of the model for storm events follows the same procedure as for tidal validation. Measured elevations are used to check model representation of head loss and/or measured velocities in the inlet or back-bay channels are compared to model currents. The usual model parameters adjusted to obtain the best agreement are friction and transition loss coefficients. If results show a poor comparison, it is advisable to carefully check the bathymetric cross-sections for accuracy. If any coefficients or depths are changed, the tidal validation computations should be rechecked with the new parameter values.

4 Statistical Analysis

Program SSEL

A Storm SELection (SSEL) program is run to create a set of elevation time series to use as an ocean forcing (external) boundary condition in DYNLET1. SSEL is a FORTRAN PC-based program (see Appendix A for the FORTRAN program listing) which accepts as input, values for *R*, *f*, stage, and mean tidal amplitude. The program develops eight hypothetical storm-plus-tide events (according to the procedures discussed in Chapter 3) and eight associated time series for input to DYNLET1. SSEL prompts the user for six inputs:

a. Two values of radius of maximum winds in nautical miles.

b. Two values of forward speed in knots.

c. Stage of surge plus tide for a specified return period.

d. Mean tide range from NOAA Tide Tables in feet.

e. Tide type (enter a 1.0 for a diurnal tide; 2.0 for semidiurnal).

f. Output time interval in hours (enter a time interval for computing the time series).

SSEL is run for each stage at a specified return period and the time-series' created (SSEL.OUT) are saved for input to DYNLET1. File SSEL.OUT must be manipulated using program FIXEXTER to create eight individual storm EXTER.DAT files for DYNLET1 and program FIXSTART to create eight individual storm START.DAT files for DYNLET1 (Cialone and Amein 1993). Velocities at specific model locations for each DYNLET1 simulation are saved on file (VELOCITY.DAT) for later analysis. These values of velocity give an estimate of velocity range for storms that can produce a given stage. Usually, the user wants to compute velocity ranges for several return period stages, e.g., the 10-, 20-, 50-, 100-, and 500-year stage.

Figure 13 displays several SSEL surge hydrographs superimposed on a mean tide at the specified four phases of the tide for a stage of 7 ft.[1] The graph shows both the pre-adjusted and adjusted time series. For the adjusted time series, the duration of high water above 4 ft msl varies from about 18 hr (only one of the events) to 3 hr.

Analysis of Velocity Data

For each known stage and interior gage where currents are to be analyzed, the eight peak flood and ebb velocities obtained from DYNLET1 are ranked from one to eight, with the smallest flood (ebb) velocity ranked as one. The cumulative probability, P, for a particular velocity from one of the eight events is given by

$$P = M/(1 + N) \tag{5}$$

where M is the order number of the event and N is the number of events, namely, $N = 8$. Thus $P = M/9$ is the probability associated with the appropriate ranked velocity. This range of velocity gives an estimate of the strength of current expected for a given stage return period, covering the range of storm durations and possible tide combinations associated with that stage.

This approach is limited in that a very small number of possible combinations are used to minimize the number of DYNLET1 simulations required. A more conservative estimate could be made by selecting more extreme values for R and f. Estimates for extreme values may be obtained from U.S. Department of Commerce (1979).

Program VANAL

Program VANAL is a PC-based FORTRAN program for analyzing frequency-indexed velocity data produced by this procedure. It accepts as input the compilation of VELOCITY.DAT files created by DYNLET1's velocity program VPLOT (Cialone and Amein 1993) and prompts the user for the following information:

a. The number of velocity gage points.

b. The length of time series saved (number of entries in the time-series).

c. The number of stages run in DYNLET1 and considered in the analysis.

d. Values of these stages (ft).

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[1] A table of factors for converting non-SI units of measurement to SI units is presented on page viii.

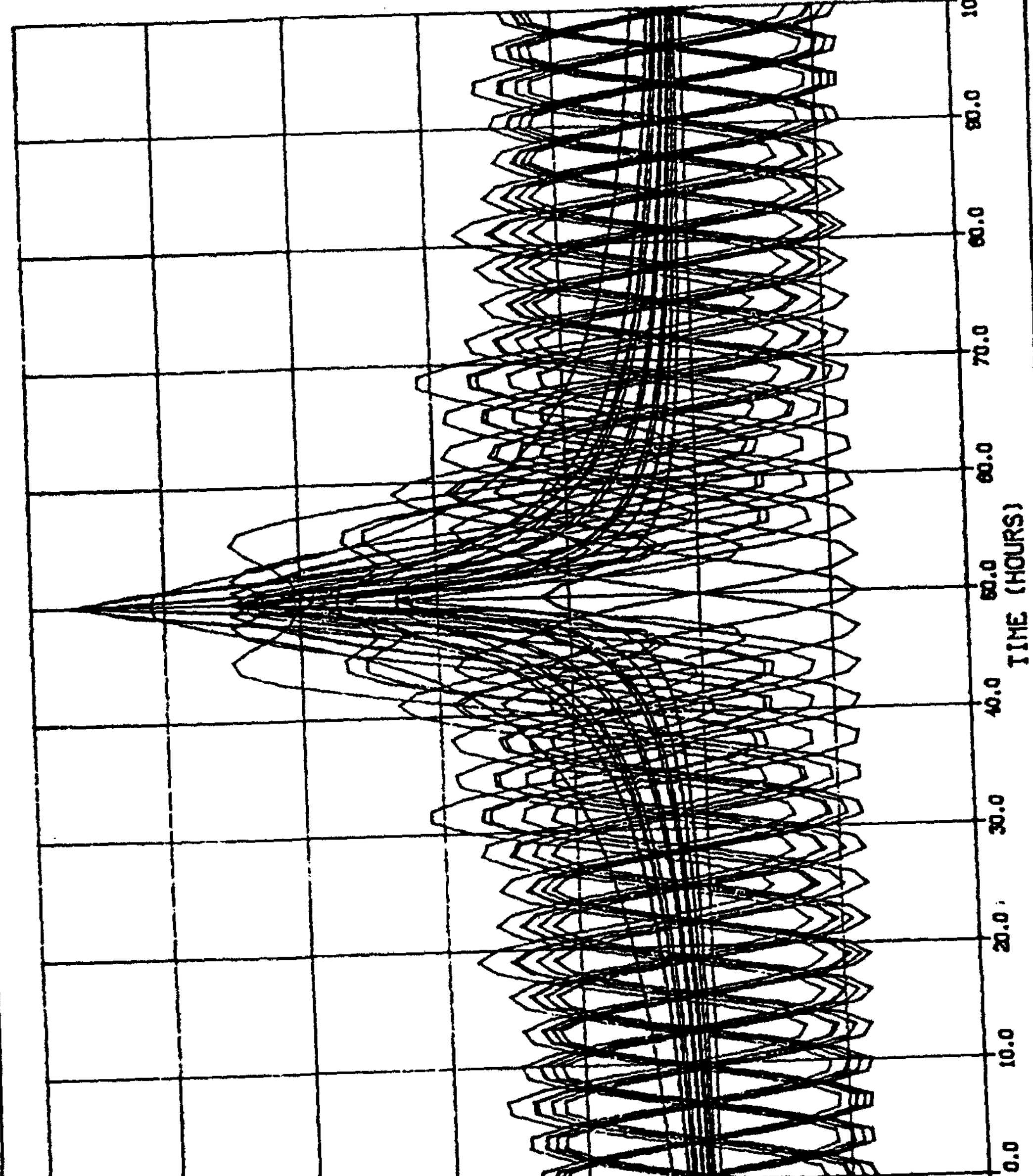

Figure 13. Surge hydrographs superimposed on a semidiurnal tide (Figure includes both pre-adjusted and adjusted surge values as well as the final surge plus tide graph)

The program computes velocity exceedance probabilities for flood and ebb conditions and produces tables of velocity and probability for each gage point and stage. For both SSEL and VANAL, SI units can be used as long as all units are consistent.

5 Brunswick Harbor Application

This section documents the application of the DYNLET1 model to Brunswick Harbor, Georgia with the objectives of: (a) calibrating the model to velocity measurements collected at the Sidney Lanier Bridge by the Georgia Department of Transportation (GDOT) Geotechnical Engineering Bureau, and (b) performing storm simulations to determine a velocity exceedance curve at the Sidney Lanier Bridge.

Grid Network

Brunswick Harbor is represented in the model by 43 cross sections or nodes in three channels (Figure 14). The channels are joined at a junction inside St. Simon Sound. Nodes 13, 14, and 25 are "junction nodes" for Channels 1, 2, and 3, respectively, and therefore have identical geometric characteristics. Channel 1 runs from the ocean side of St. Simon Sound to the junction inside St. Simon Sound (Node 13), Channel 2 runs from the junction (Node 14) north through the Mackay River, and Channel 3 runs from the junction (Node 25) west through the Brunswick River, under the Sidney Lanier Bridge and north through Turtle Creek.

Cross-sectional data were taken from NOAA Chart 11506 (Scale 1:40,000) with the reference datum being mean lower low water (mllw). Values of Manning's coefficient of friction were specified at every point on every cross-section. An initial value of 0.02 was used everywhere, which is reasonable for a sandy bottom. Friction values for marshy areas can be revised to obtain a better representation of hydrodynamics in these areas. Because there are no severe constrictions at Brunswick Harbor, transition losses were eliminated by setting the transition loss coefficient to zero at every cross section. No adjustments to this value were needed in the calibration procedure.

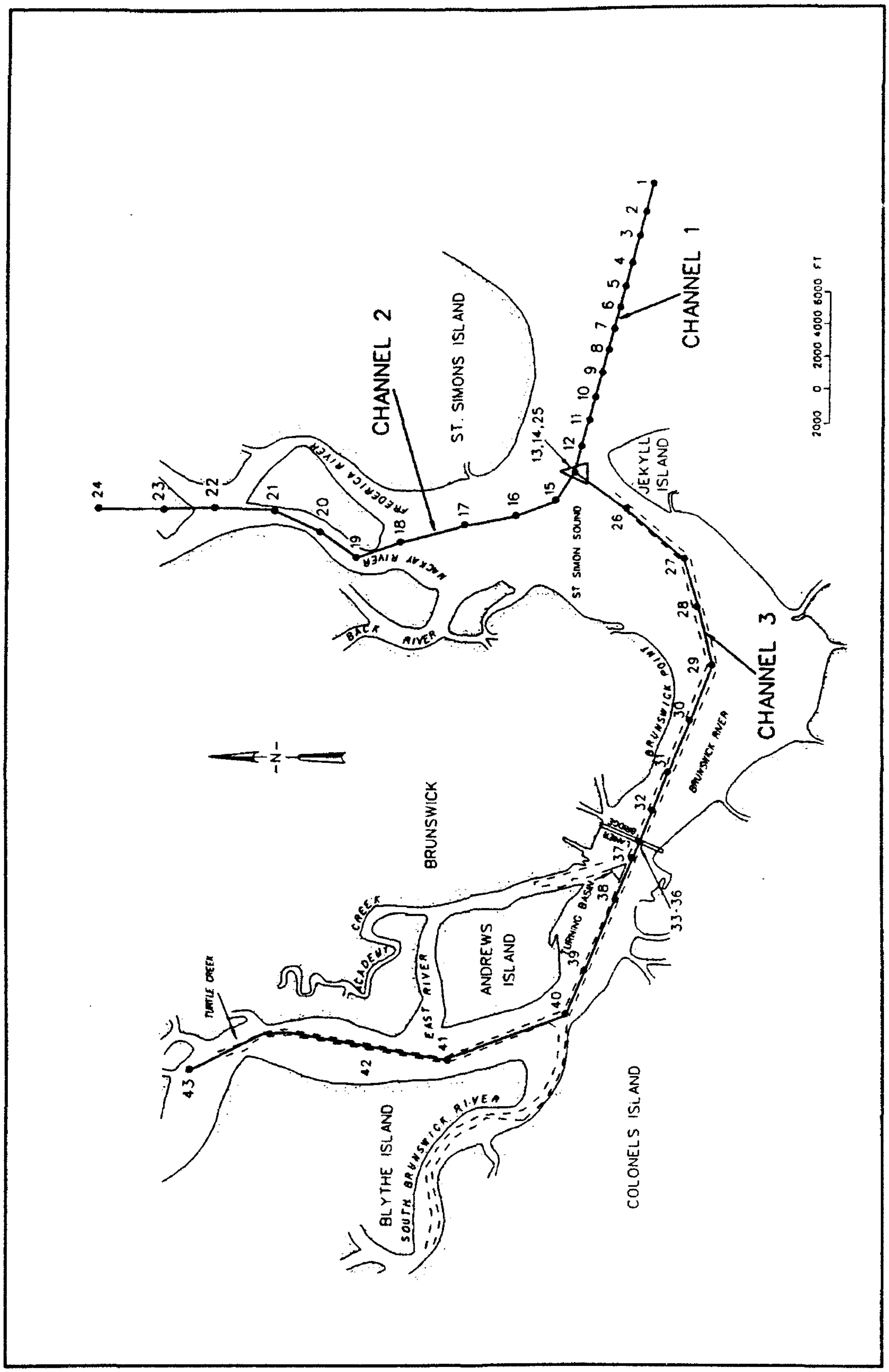

Figure 14. DYNLET1 grid network for Brunswick Harbor, Georgia

Tidal Calibration

At the ocean boundary, Node 1, a Type 1 boundary was specified indicating values of water surface elevation as a function of time were used as the boundary forcing function. Water surface elevation data obtained near the Sidney Lanier Bridge during the GDOT velocity study (27 October 1992) (Figure 15) were shifted in phase to approximate conditions occurring at the ocean boundary node.

At the end nodes in the Mackay River and Turtle Creek (Nodes 24 and 43), a Type 2 (discharge) boundary condition was specified. No information was available for stream discharge nor for surface elevations upstream. Discharge was assumed negligible and set equal to zero at these boundaries.

Channels and cross sections were sketched onto a NOAA chart, cross-section elevations were read from the NOAA chart, time-dependent water surface elevation data were read from a GDOT plot, and all data were entered into the appropriate input files using EDINLET. The model was run several times, output results plotted, and after some adjustments the model accurately calculated velocity at the Sidney Lanier Bridge. A constant friction value of 0.025 and transition loss coefficient of 0.0 was used to obtain the best comparison with measured data.

Figures 16 and 17 show water surface fluctuation and velocity model results near the Sidney Lanier Bridge. As previously stated, the water surface fluctuation at the bridge was shifted in phase and used as the ocean boundary forcing function. Figure 16 shows that the model reproduces the actual water surface levels at the bridge. In addition, velocity data near the bridge are represented by the model. Graphics for all results are given in Appendix C.

Storm Selection and Simulation

For Brunswick, most of the storms occurring in the area are alongshore storms. However, it is recommended that the most conservative estimate (lowest value) of forward speed be used in the simulations. Values of R and f chosen for Brunswick are shown in Figures 18 and 19. Landfalling and alongshore data for f have been combined to produce a single forward speed probability distribution diagram.

The GDOT provided NOAA data (Ho 1974) for stage frequency at the Florida/Georgia border (Figure 20). For example computations, stages at return periods of 10, 50, 100, and 500 years, namely, 7.1, 12.0, 14.5, and 20.0 ft, respectively, were chosen as input to SSEL and DYNLET1 was run to estimate velocity behavior. For tidal input, NOAA Tide Tables (U.S. Department of Commerce 1982) provide information on the mean tide range. Figure 21 displays a page from the 1983 Tide Tables for the Brunswick,

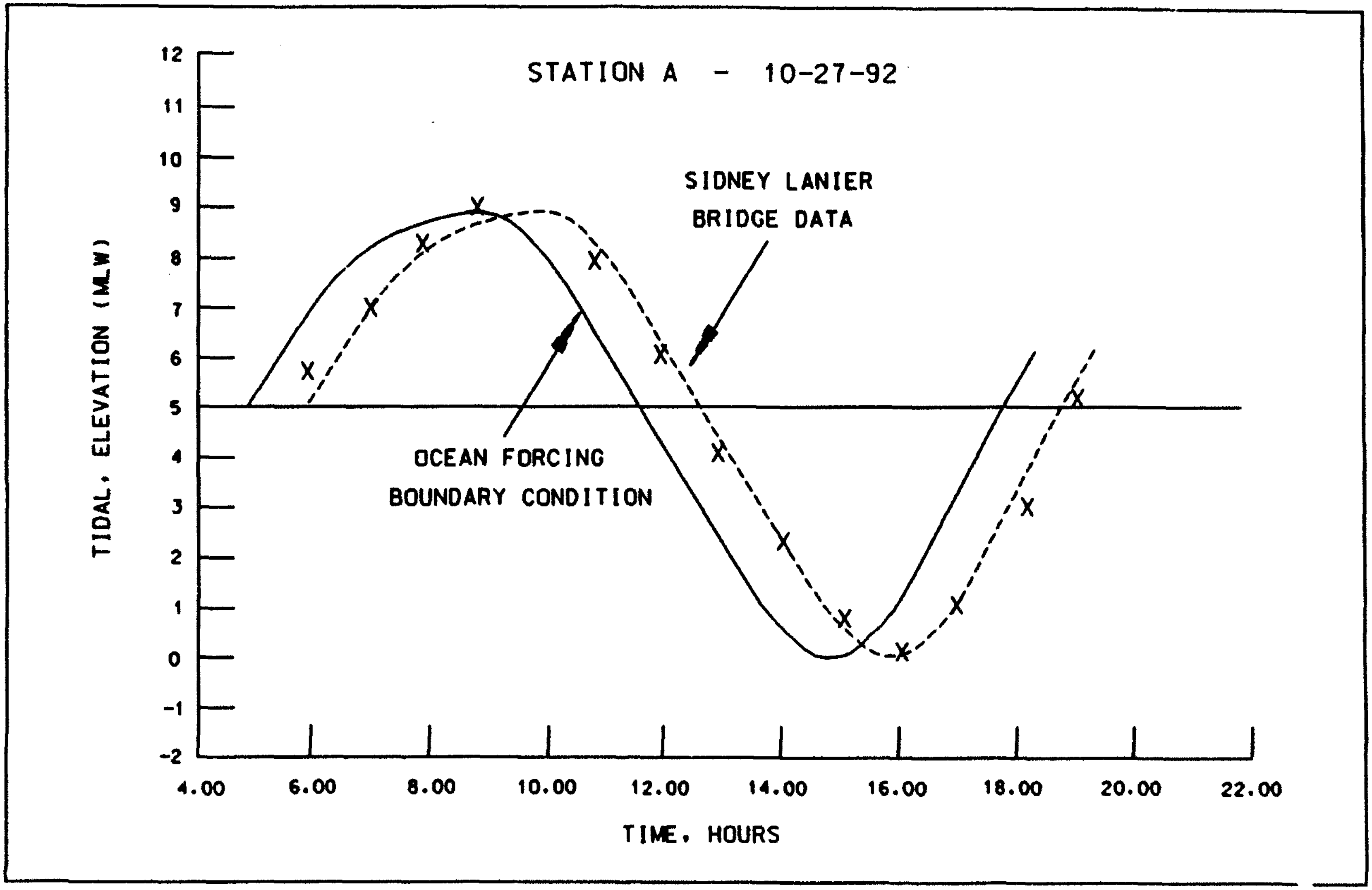

Figure 15. Measured water elevation at Sidney Lanier Bridge and adjusted values used for the ocean boundary condition

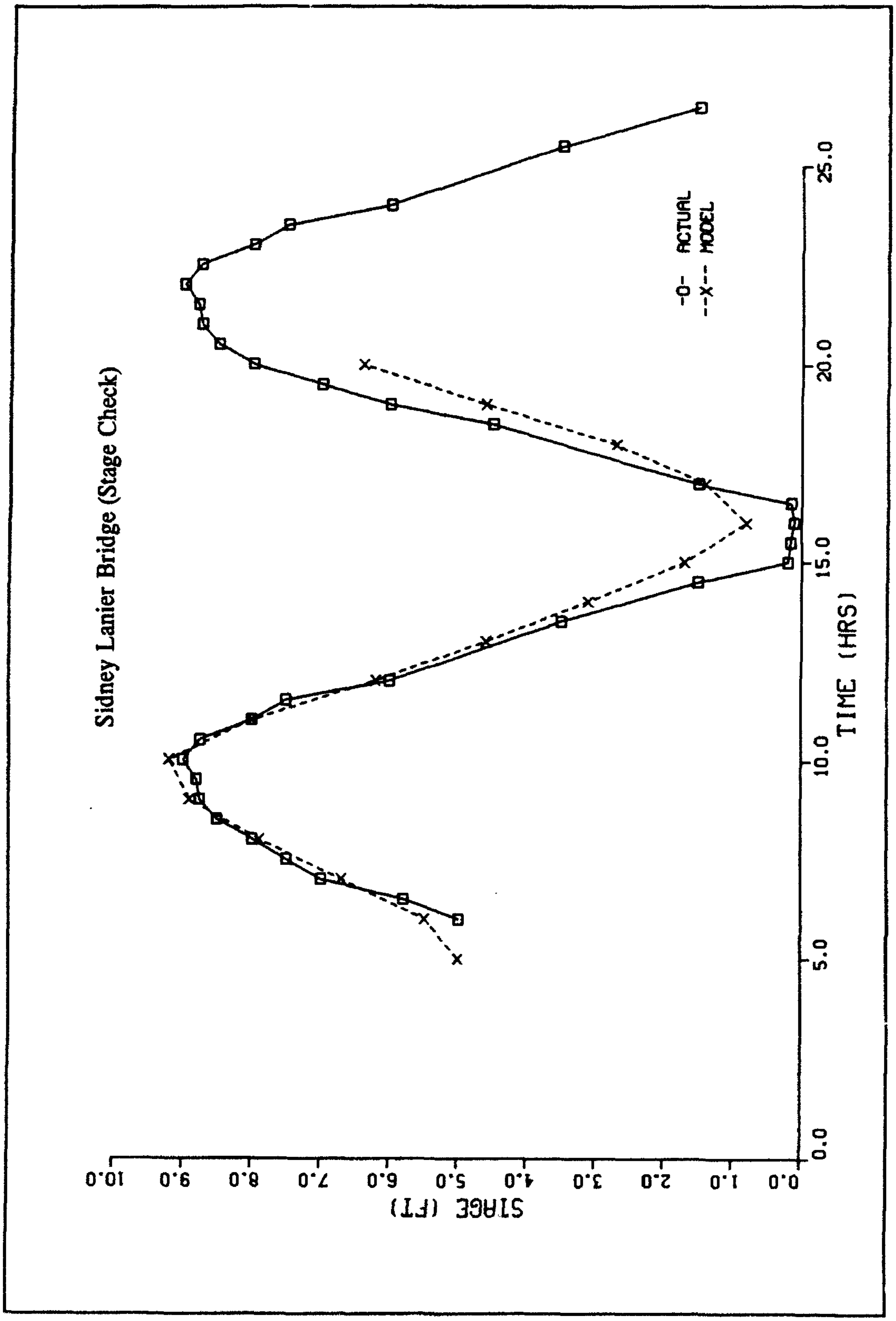

Figure 16. Comparison of calibrated model surface elevation results with measured data at Brunswick Harbor

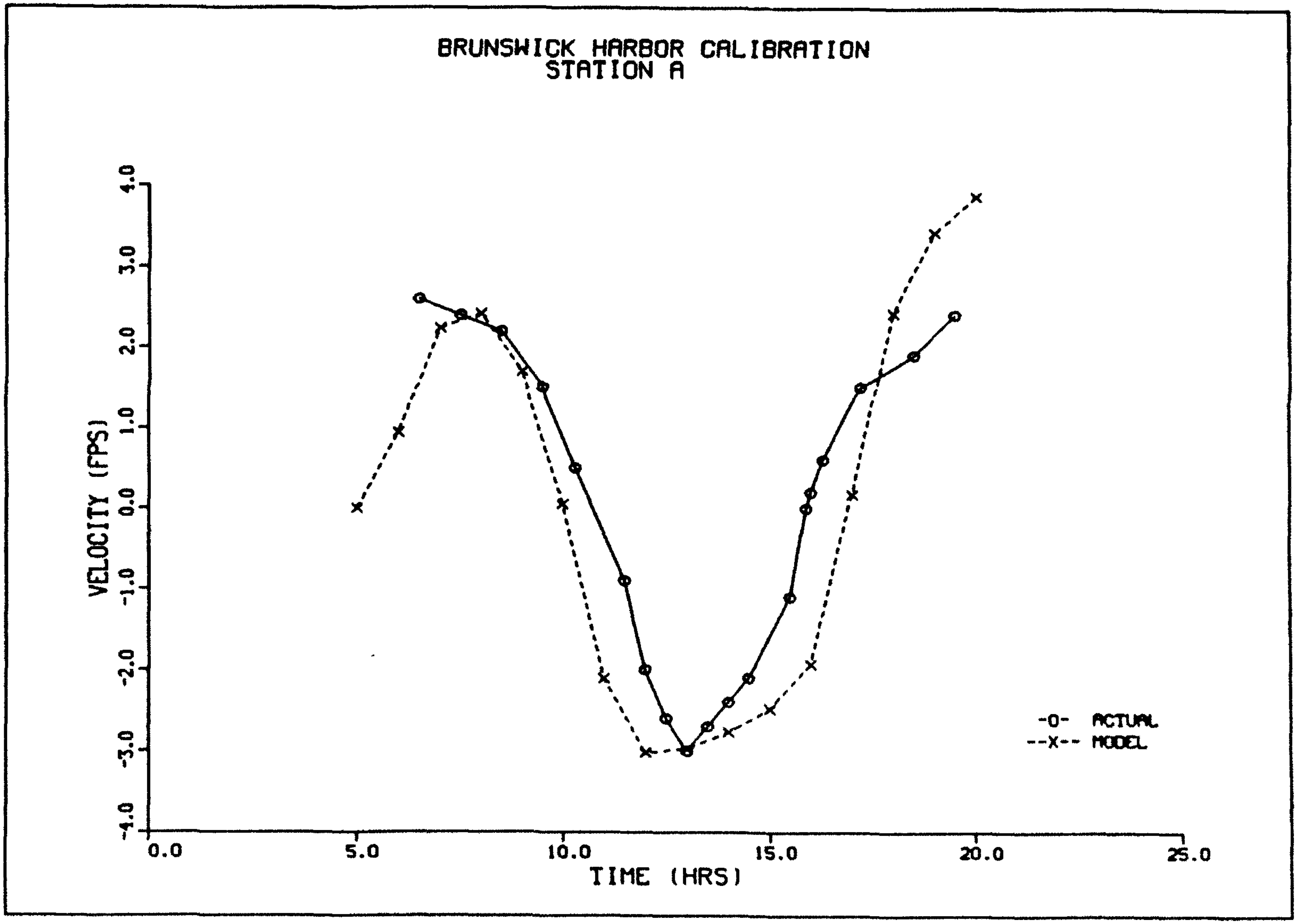

Figure 17. Comparison of calibrated model velocity results with measured data at Brunswick Harbor

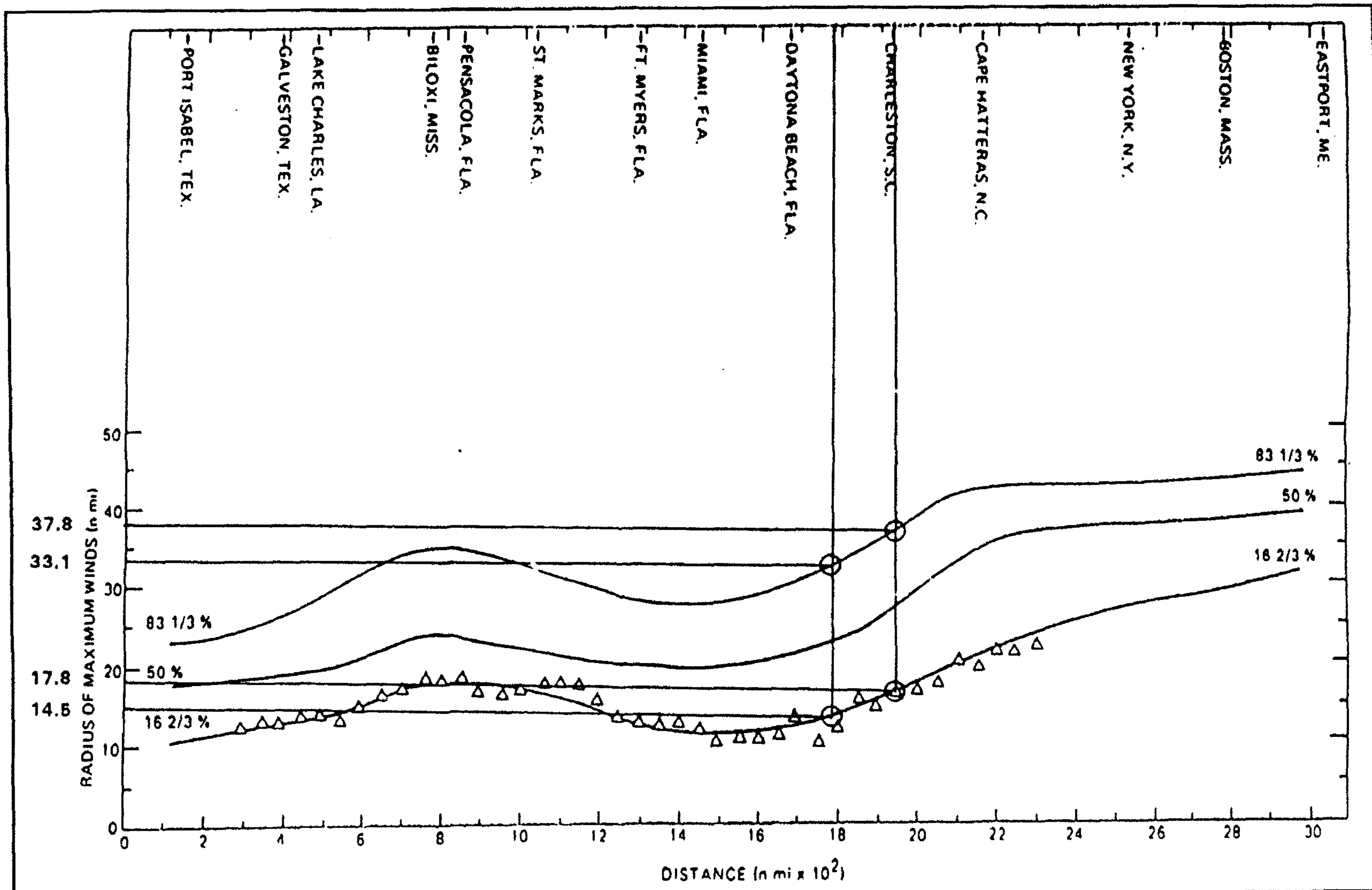

Figure 18. Probability distribution of radius of maximum winds of hurricanes, Gulf and east coasts (1900-73). Numbered lines denote the percent of storms with R equal to or less than the value indicated along the ordinate. Plotted points (Δ) are taken from frequency analyses at 50-n.m. intervals for the 16-2/3 percentile

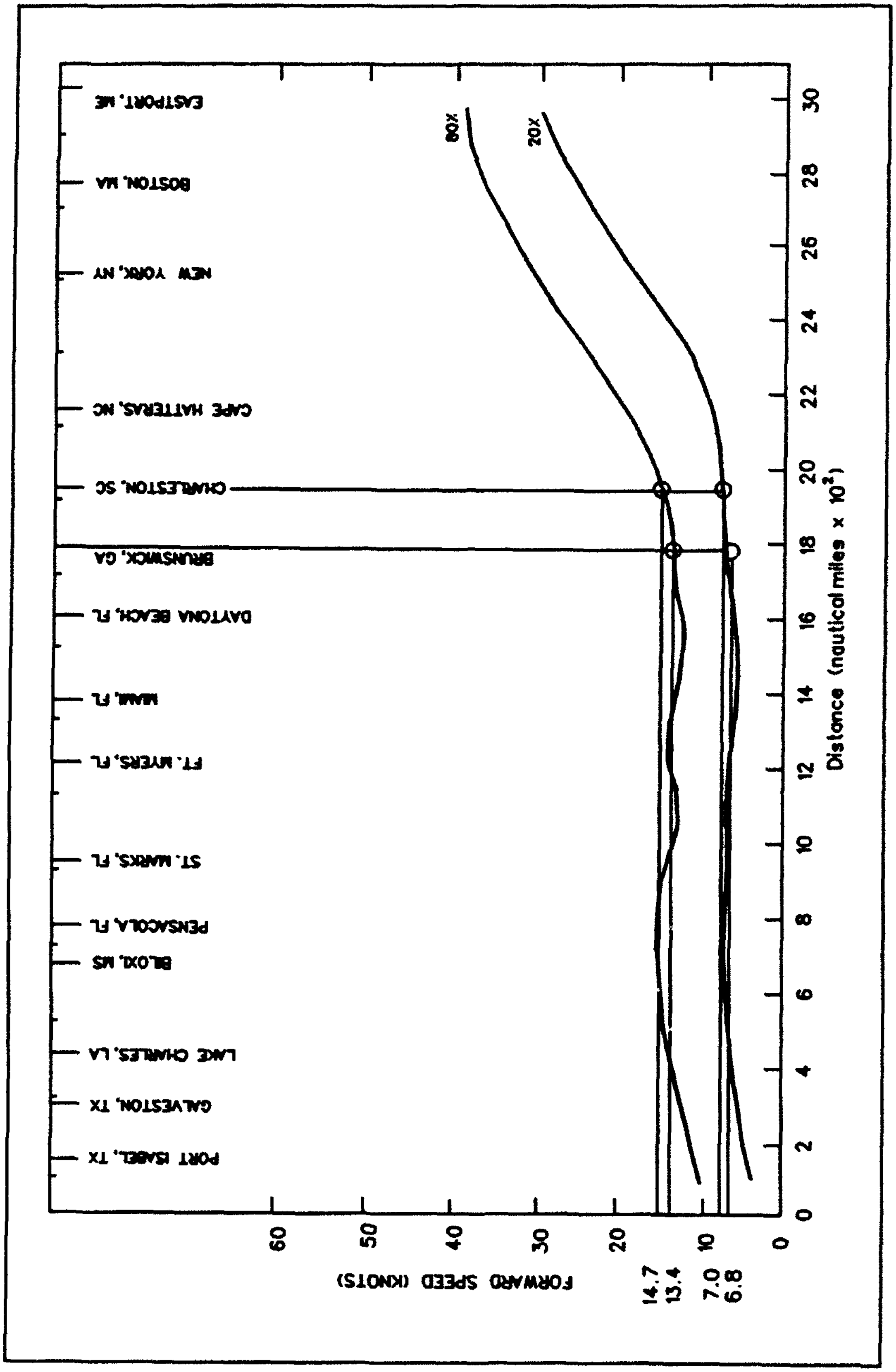

Figure 19. Probability distribution of forward speed for hurricanes, 1886-1973. Numbered lines denote the percent of storms with forward speed equal to or less than the value indicated along the ordinate. Plotted points (Δ) are taken from frequency analyses for the 80th percentile

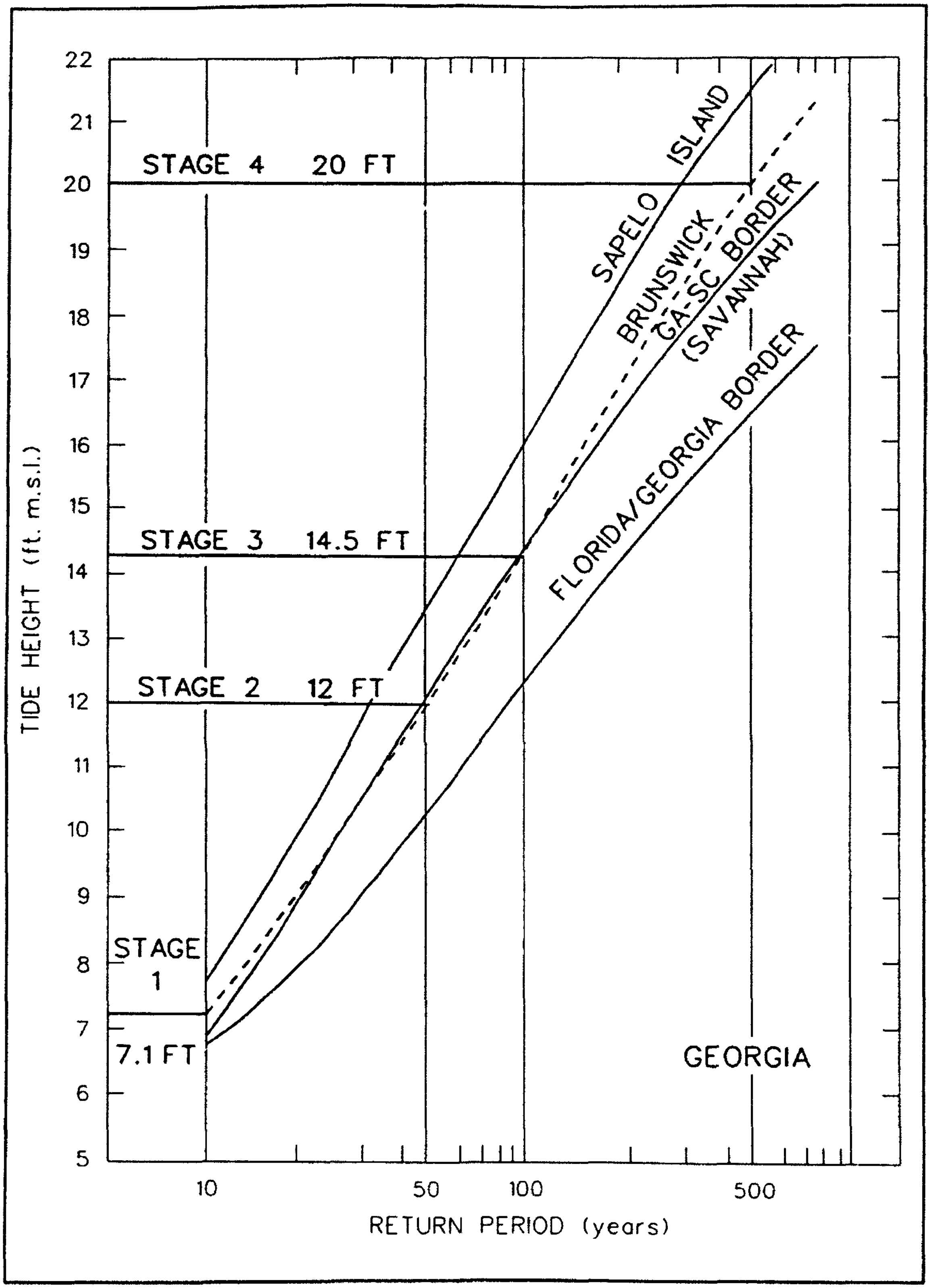

Figure 20. Storm-plus-tide stage-frequency curves on the open coast at Florida/Georgia border, Brunswick, Sapelo Island, and Savannah, Georgia

NO.	PLACE	POSITION Lat.	Long.	DIFFERENCES Time High Water	Time Low Water	Height High Water	Height Low Water	RANGES Mean	Spring	Mean Tide Level
		° ′ N	° ′ W	h. m.	h. m.	ft	ft	ft	ft	ft
	St. Catherines and Sapelo Sounds Time meridian, 75°W			on SAVANNAH RIVER ENT., p.100						
2753	North Newport River	31 40	81 16	+0 58	+0 33	+0.7	0.0	7.6	8.9	3.8
2755	South Newport River	31 38	81 16	+0 39	+0 44	+0.5	0.0	7.4	8.7	3.7
2756	Dallas Bluff, Julienton River	31 35	81 19	+0 50	+1 01	+0.7	0.0	7.6	8.9	3.8
2757	Blackbeard Island	31 32	81 12	+0 20	+0 19	0.0	0.0	6.9	8.1	3.4
2758	Dog Hammock, Sapelo River	31 32	81 16	+0 31	+0 23	+0.2	0.0	7.1	8.3	3.6
2759	Pine Harbor, Sapelo River	31 33	81 22	+1 05	+1 01	+0.3	0.0	7.2	8.4	3.6
2760	Eagle Creek, Mud River	31 31	81 17	+0 23	+0 16	+0.3	0.0	7.2	8.4	3.6
2761	Mud River, at Old Teakettle Creek	31 29	81 19	+0 47	+0 43	+0.5	0.0	7.4	8.7	3.7
	Doboy and Altamaha Sounds									
2762	Blackbeard Creek, Blackbeard Island	31 29	81 13	+0 21	+0 44	-0.4	0.0	6.5	7.6	3.3
2763	Sapelo Island	31 23	81 17	0 00	+0 02	-0.1	0.0	6.8	8.0	3.4
2765	Hudson Creek entrance	31 27	81 21	+0 39	+0 28	+0.3	0.0	7.2	8.4	3.6
2767	Threemile Cut entrance, Darien River	31 21	81 23	+0 46	+0 52	+0.2	0.0	7.1	8.3	3.5
2769	Darien, Darien River	31 22	81 26	+1 10	+1 12	+0.4	0.0	7.3	8.5	3.6
2771	Wolf Island	31 20	81 19	+0 06	+0 35	-0.3	0.0	6.6	7.7	3.3
2773	Champney Island, South Altamaha River	31 20	81 28	+1 12	+2 30	-1.7	0.0	5.2	6.1	2.6
2775	Hampton River entrance	31 13	81 19	+0 18	+0 01	-0.3	0.0	6.6	7.8	3.3
2777	Jones Creek entrance, Hampton River	31 18	81 20	+1 05	+0 10	+0.3	0.0	7.2	8.5	3.6
	St. Simons Sound									
2779	St. Simons Sound Bar	31 06	81 19	+0 01	-0 05	-0.4	0.0	6.5	7.6	3.2
2781	St. Simons Light	31 08	81 24	+0 24	+0 28	-0.3	0.0	6.6	7.7	3.3
2783	Frederica River	31 13	81 24	+0 50	+0 53	+0.3	0.0	7.2	8.4	3.6
2785	Troup Creek entrance, Mackay River	31 13	81 26	+0 54	+0 49	+0.3	0.0	7.2	8.4	3.6
2787	Brunswick, East River	31 09	81 30	+0 55	+0 40	+0.4	0.0	7.3	8.5	3.6
	Turtle River									
2789	Allied Chemical Corp. docks	31 11	81 31	+1 05	+0 39	+0.7	0.0	7.6	8.9	3.8
2791	Dillard Creek	31 14	81 34	+1 34	+0 59	+1.1	0.0	8.0	9.4	4.0
2793	Buffalo River entrance	31 13	81 35	+1 39	+0 55	+1.1	0.0	8.0	9.4	4.0
2795	Highway bridge, South Brunswick River	31 09	81 34	+1 09	+0 46	+0.7	0.0	7.6	8.9	3.8
2797	Jekyll Point	31 01	81 26	+0 28	+0 28	-0.3	0.0	6.6	7.7	3.3
2799	Jointer Island, Jointer Creek	31 06	81 30	+1 02	+0 49	+0.3	0.0	7.2	8.4	3.6
	Little Satilla River									
2801	2.5 miles above mouth	31 04	81 30	+0 47	+0 49	-0.1	0.0	6.8	8.0	3.4
2803	8 miles above mouth	31 06	81 34	+1 15	+1 20	+0.4	0.0	7.3	8.5	3.6
2805	Below Spring Bluff	31 10	81 37	+2 00	+1 49	+0.6	0.0	7.5	8.8	3.7
2807	Dover Bluff, Dover Creek	31 01	81 32	+0 57	+0 49	+0.1	0.0	7.0	8.2	3.5
	Satilla River									
2809	Todd Creek entrance	30 58	81 31	+0 43	+0 59	-0.2	0.0	6.7	7.8	3.3
2811	Bailey Cut, 0.8 mile west of	30 59	81 36	+0 57	+1 20	0.0	0.0	6.9	8.1	3.4
2813	Ceylon	30 58	81 39	+1 25	+1 53	-0.3	0.0	6.6	7.7	3.3
2815	Burnt Fort	30 57	81 54	+4 46	+5 23	*0.46	*0.46	3.2	3.7	1.6
2817	Cumberland Wharf, Cumberland River	30 56	81 27	+0 40	+0 42	-0.1	0.0	6.8	8.0	3.4
2819	Floyd Creek, 2.8 miles above entrance	30 56	81 30	+0 59	+0 39	+0.2	0.0	7.1	8.3	3.5
	GEORGIA and FLORIDA Cumberland Sound									
2821	St. Marys Entrance, north jetty	30 43	81 26	+0 15	+0 15	-1.1	0.0	5.8	6.8	2.9
2823	Crooked River entrance	30 51	81 29	+1 23	+1 12	-0.1	0.0	6.8	8.0	3.4
2825	Harrietts Bluff, Crooked River	30 52	81 35	+2 09	+2 12	-0.5	0.0	6.4	7.5	3.2
2827	St. Marys, St. Marys River	30 43	81 33	+1 21	+1 13	-0.9	0.0	6.0	7.0	3.0
2829	Crandall, St. Marys River	30 43	81 37	+2 10	+1 59	-1.8	0.0	5.1	6.0	2.5
				on MAYPORT, p.108						
2831	Fernandina Beach (outer coast)	30 38	81 26	-0 18	-0 01	+1.2	0.0	5.7	6.7	2.8
2833	Fernandina Beach, Amelia River	30 40	81 28	+0 32	+0 16	+1.5	0.0	6.0	7.0	3.0
2835	Chester, Bells River	30 41	81 32	+0 49	+0 41	+1.9	0.0	6.4	7.5	3.2
2837	S.C.L. RR. bridge, Kingsley Creek	30 38	81 29	+0 59	+0 43	+1.5	0.0	6.0	7.0	3.0
	FLORIDA Nassau Sound and Fort George River									
2839	Nassau Sound	30 31	81 27	-0 03	+0 06	+0.9	0.0	5.4	6.3	2.7
2841	Amelia City, South Amelia River	30 35	81 28	+0 54	+1 03	+1.1	0.0	5.6	6.6	2.8
2843	Nassauville, Nassau River	30 34	81 31	+1 04	+1 37	+0.3	0.0	4.8	5.6	2.4
2845	Mink Creek entrance, Nassau River	30 32	81 34	+1 58	+2 32	-0.6	0.0	3.9	4.6	1.9
2847	Halfmoon Island, highway bridge	30 34	81 36	+3 00	+3 21	-1.0	0.0	3.5	4.1	1.7
2849	Sawpit Creek entrance	30 31	81 27	-0 02	+0 [illegible]	+0.5	0.0	5.0	5.8	2.5
2851	Fort George Island, Fort George River	30 26	81 26	+0 29	+0 39	+0.3	0.0	4.8	5.6	2.4
	FLORIDA, St. Johns River									
2853	South Jetty	30 24	81 23	-0 23	-0 17	+0.4	0.0	4.9	5.7	2.4
2855	MAYPORT	30 24	81 26	Daily predictions				4.5	5.3	2.3

Endnotes can be found at the end of table 2.

Figure 21. Predicted tide at Brunswick, Georgia

Georgia, area. The mean range for the ocean gage (St. Simons Sound Bar) is 6.5 ft giving an amplitude of 3.25 ft.

SSEL is run for each stage and a set of eight files of surge-plus-tide time series is saved for later processing in DYNLET1. For Brunswick, the data used in SSEL are summarized as follows:

R = 33.1 and 14.5 n.m.
f = 13.4 and 6.8 knots
S_{tot} = 7.1, 12.0, 14.5, and 20.0 ft (four SSEL runs)
M_2 = 3.25 ft (mean amplitude)
2. = Entered to indicate semidiurnal tide
0.5 = Entered time interval for DYNLET1 time series

These four SSEL runs produced eight time series hydrographs for each stage. For this example, 32 DYNLET1 simulations were made and velocities at one selected bridge pier location were saved for later analysis.

Velocity-Frequency Analysis

Program VANAL was run for the Brunswick data produced by the 32 DYNLET1 simulations. Data required included 1 velocity gage point, a time series length of 41 (1 hr entries from hour 30 to 70), 4 stages, and stage values of 7.1, 12.0, 14.5, and 20.0 ft. Probability tables created by VANAL are given in Table 1. These tables show the percent of surge-plus-tide events with velocities at the bridge pier which are equal to or less than the value of velocity indicated (for flood and ebb conditions).

This same information can be expressed in graphical form (Figure 22). As discussed previously, any given stage for a particular return period could be produced by combinations of varying storm intensities, durations, and tidal phase. While only eight events at a particular stage were run, Figure 22 shows a linear-with-time estimate of probability exceedance seems appropriate.

An example interpretation of these results might be: in designing a project for a 200 year stage of 16.9 ft, the range of flood velocities expected are from 6.5 to 16.9 ft/sec with the expectation that a current exceeding 16.9 ft/sec for a 200 year stage would occur less than 11 percent of the time (see Figure 22).

Table 1
Peak Flood and Ebb Velocities Near Bridge Pier and Exceedance Probabilities at Four Stages at Brunswick Harbor, Georgia

	Stage 1: 7.1 ft			Stage 2: 12.0 ft		
Rank	Flood Velocity (ft/sec)	Ebb Velocity (ft/sec)	Cumulative Probability	Flood Velocity (ft/sec)	Ebb Velocity (ft/sec)	Cumulative Probability
1	5.55	-5.21	11	7.67	-5.25	11
2	6.45	-5.38	22	7.67	-6.20	22
3	6.55	-5.47	33	8.52	-6.59	33
4	6.56	-5.69	44	8.80	-7.06	44
5	6.79	-5.77	56	9.67	-7.99	56
6	6.82	-5.95	67	9.84	-8.18	67
7	7.04	-6.15	78	11.02	-8.57	78
8	8.80	-7.28	89	13.33	-10.36	89
	Stage 3: 14.5 ft			**Stage 4: 20.0 ft**		
Rank	**Flood Velocity (ft/sec)**	**Ebb Velocity (ft/sec)**	**Cumulative Probability**	**Flood Velocity (ft/sec)**	**Ebb Velocity (ft/sec)**	**Cumulative Probability**
1	8.25	-6.40	11	9.20	-6.99	11
2	8.83	-6.45	22	9.36	-7.57	22
3	9.50	-6.84	33	10.67	-7.59	33
4	9.73	-7.39	44	12.04	-9.68	44
5	10.80	-8.82	56	14.39	-10.95	56
6	11.00	-9.63	67	15.54	-13.12	67
7	13.14	-10.04	78	18.11	-13.36	78
8	15.41	-12.10	89	18.98	-16.41	89

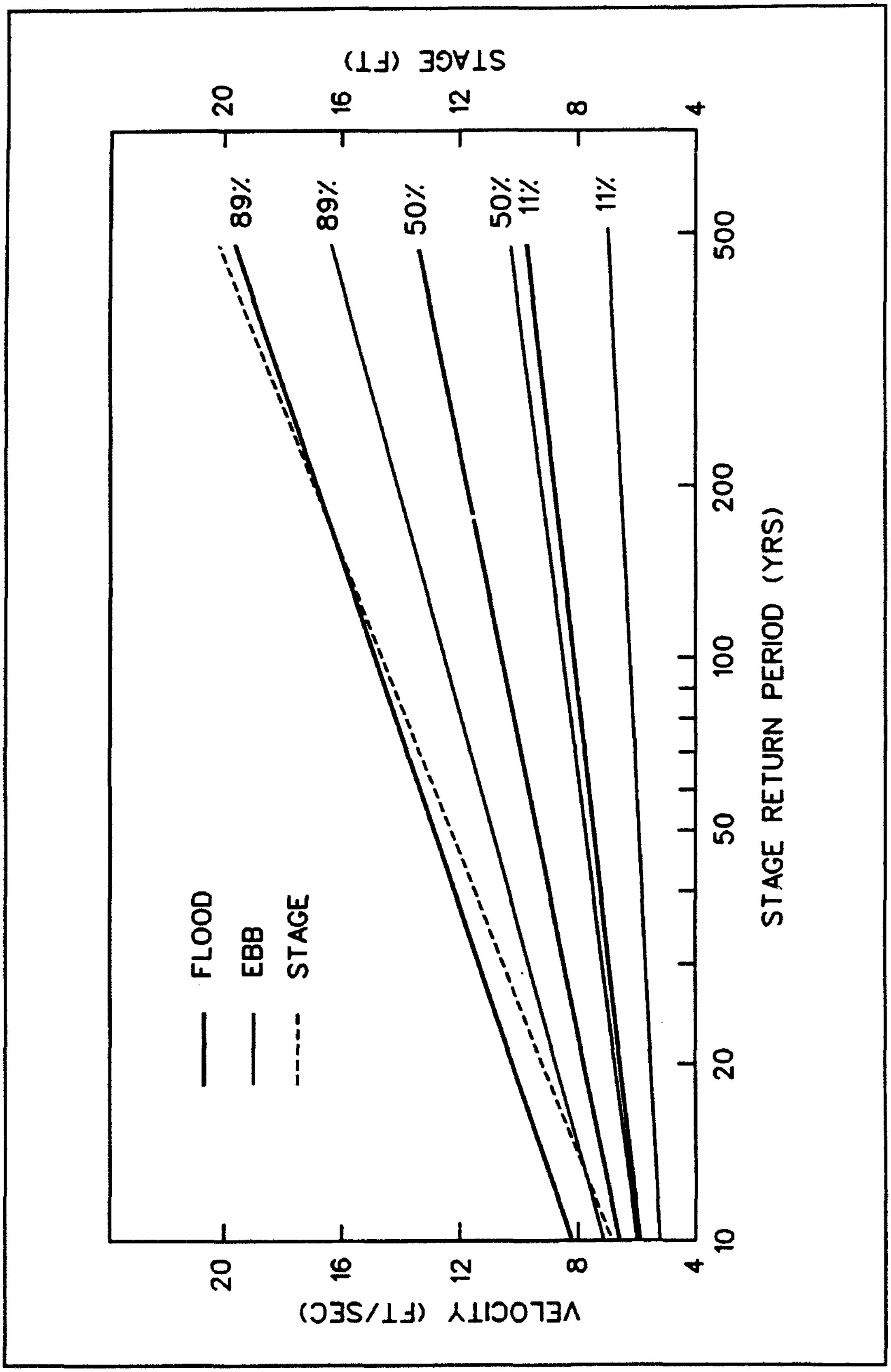

Figure 22. Graphical presentation of results from Table 1

6 Charleston Harbor Application

Grid Network

Charleston Harbor is represented in the model by 65 cross sections or nodes in 11 channels (Figure 23). The channels are joined at flow convergence points, and for Charleston Harbor, six such junctions are used to represent these convergence points. Nodes 6, 7, and 11 are junction nodes for Channels 1, 2, and 3; Nodes 14, 18, and 26 are junction nodes for Channels 3, 4, and 6; and so forth. Channel 1 runs from the ocean side of the inlet to the junction inside the inlet (Node 6), Channels 2 and 5 cover Ashley River, Channels 3 and 4 traverse around Shutes Folley Island, Channel 6 is a short reach extending from Shutes Folley Island to Drum Island, Channels 7 and 10 traverse Wando River, Channels 8 and 11 traverse Cooper River, and Channel 9 negotiates around the north side of Drum Island.

Cross-sectional data were taken from NOAA chart 11524 (scale 1:20,000) with the reference datum being mllw. Values of Manning's coefficient of friction were specified at every point on every cross section. An initial value of 0.02 was used everywhere, which is reasonable for a sandy bottom. Friction values for marshy areas can be revised to obtain a better representation of hydrodynamics in these areas. Because there are no severe constrictions at Charleston Harbor, transition losses were eliminated by setting the transition loss coefficient to zero at every cross section.

Tidal Calibration

At the ocean boundary, Node 1, a Type 1 boundary was specified indicating values of water surface elevation as a function of time were used as the boundary forcing function. Water surface elevation data were obtained from WES Report H-76-9 (Benson 1976), which describes a physical model study of Charleston Harbor.

At the end nodes in the Ashley, Wando, and Cooper Rivers (Nodes 25, 58, and 65, respectively), a Type 2 (discharge) boundary condition was specified.

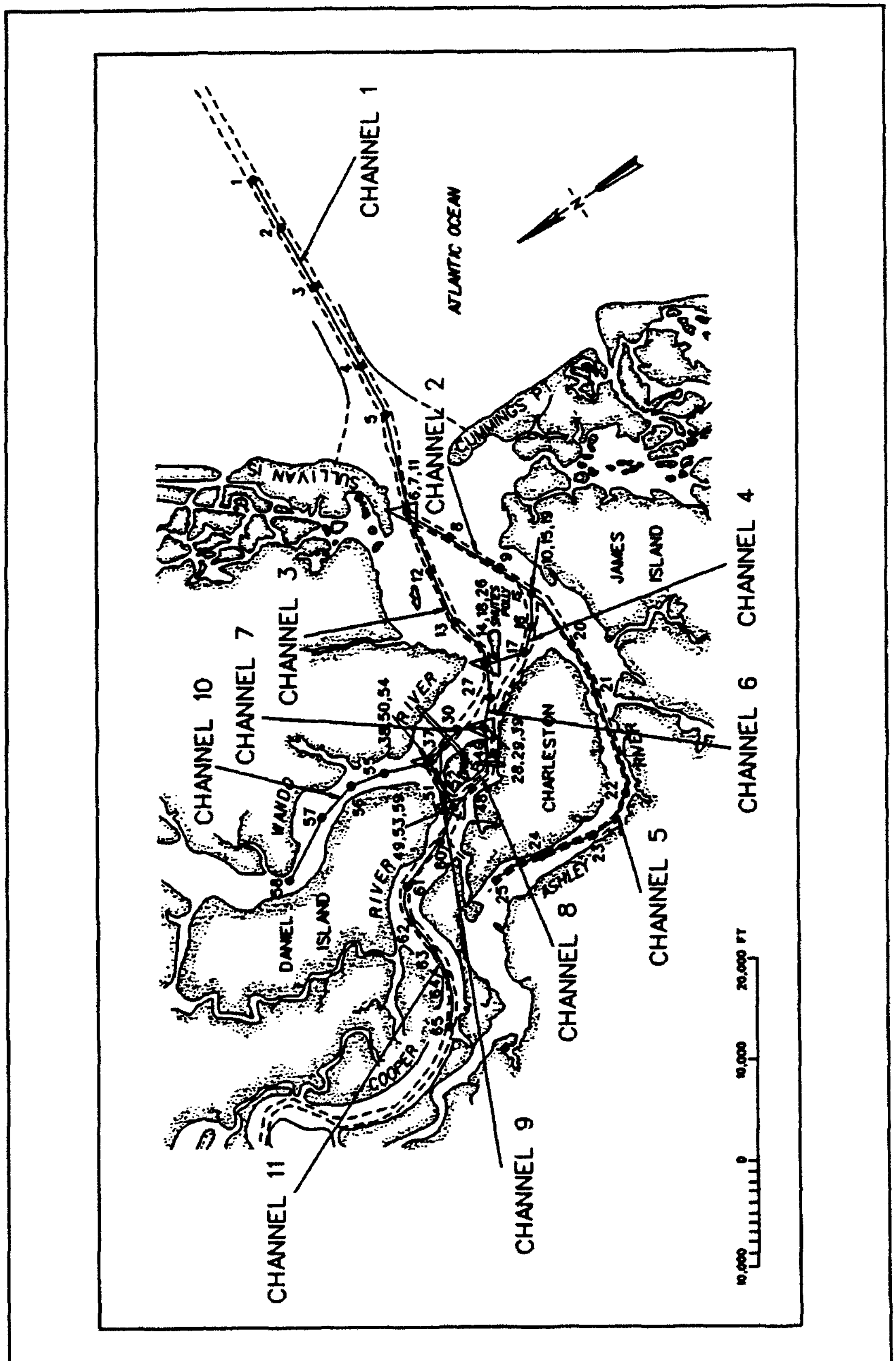

Figure 23. DYNLET1 grid network for Charleston Harbor, South Carolina

Information on stream discharge was obtained from the WES report by Benson (1976). Current data are also available for comparison to model results.

Channels and cross sections were sketched onto a NOAA chart, cross-section elevations were read from the NOAA chart, time-dependent water surface elevation data were read from Benson (1976), and all data were entered into the appropriate input files using EDINLET.

Storm Selection and Simulation

Charleston is similar to Brunswick in that most of the storms occurring in the area are alongshore storms. Again, it is recommended that conservative estimates of R and f be used in the simulations. Values chosen for Charleston are shown in Figures 18 and 19. For tidal input, NOAA Tide Tables (U.S. Department of Commerce 1982) provide information on the mean tide range. Figure 24 displays a page from the 1983 Tide Tables for the Charleston, South Carolina, area. The mean range for the ocean gage (entrance - North Jetty) is 5.2 ft giving an amplitude of 2.6 ft. The stage-frequency curve (Myers 1975) for Charleston (Figure 25) can be used for determining stage at specific return periods for Charleston.

Results from this application are not included in the report and the reader is encouraged to use this case as a training example.

TABLE 2. — TIDAL DIFFERENCES AND OTHER CONSTANTS, 1983 223

NO.	PLACE	POSITION Lat.	POSITION Long.	DIFFERENCES Time High Water	DIFFERENCES Time Low Water	DIFFERENCES Height High Water	DIFFERENCES Height Low Water	RANGES Mean	RANGES Spring	Mean Tide Level
		° ′ N	° ′ W	h. m.	h. m.	ft	ft	ft	ft	ft
	South Carolina, Winyah Bay Time meridian, 75°W			on CHARLESTON, p.96						
2523	Frazier Point	33 19	79 17	+1 19	+2 03	-1.7	0.0	3.5	4.1	1.7
2525	Georgetown, Sampit River	33 22	79 17	+1 27	+2 25	*0.63	*0.63	3.3	3.9	1.6
2527	Georgetown, Pee Dee River bridge	33 22	79 16	+1 34	+2 35	*0.63	*0.63	3.3	3.9	1.6
	Waccamaw River									
2529	Schooner Creek entrance	33 27	79 10	+2 21	+3 18	*0.62	*0.62	3.2	3.8	1.6
2531	Wachesaw Ldg., 1 mile south of	33 33	79 08	+3 06	+4 08	*0.56	*0.56	2.9	3.4	1.4
2533	Bull Creek entrance	33 36	79 06	+3 38	+4 41	*0.44	*0.44	2.3	2.7	1.1
2535	Enterprise Landing	33 40	79 04	+4 54	+5 31	*0.38	*0.38	2.0	2.4	1.0
2537	Toddville	33 45	79 04	+7 10	+7 07	*0.25	*0.25	1.3	1.5	0.6
2539	Conway	33 50	79 02	+7 47	+7 56	*0.23	*0.23	1.2	1.4	0.6
	SOUTH CAROLINA, Outer Coast-Con.									
2541	North Santee River Inlet	33 08	79 15	-0 16	0 00	-0.7	0.0	4.5	5.3	2.2
2543	Minim Creek ent., North Santee River	33 12	79 16	-0 02	+1 02	-1.3	0.0	3.9	4.6	1.9
2544	Cedar Island Point, South Santee River	33 07	79 16	-0 23	+0 04	-1.1	0.0	4.1	4.8	2.0
2545	Brown Island, South Santee River	33 09	79 20	+0 20	+1 27	-1.1	0.0	4.1	4.8	2.0
2547	Cape Romain	33 01	79 21	-0 29	-0 21	-0.5	0.0	4.7	5.5	2.3
2549	Cape Romain, 46 miles east of	33 05	78 26	-1 12	-1 17	-1.1	0.0	4.1	4.8	2.0
	Bull Bay									
2551	Five Fathom Creek entrance	33 00	79 30	-0 13	-0 11	-0.3	0.0	4.9	5.8	2.4
2553	McClellanville, Jeremy Creek	33 05	79 28	+0 20	+0 21	-0.1	0.0	5.1	6.0	2.5
2555	Harbor River entrance	33 02	79 32	-0 04	+0 32	-0.3	0.0	4.9	5.8	2.4
2557	Jack Creek entrance	32 56	79 35	-0 21	-0 19	-0.2	0.0	5.0	5.9	2.5
2559	Wharf Creek entrance	32 55	79 37	+0 05	-0 12	-0.1	0.0	5.1	6.0	2.5
2561	Sewee Bay	32 56	79 39	+0 06	+0 07	-0.2	0.0	5.0	5.9	2.5
2563	Capers Inlet	32 51	79 42	-0 16	-0 14	0.0	0.0	5.2	6.1	2.6
2565	Dewees Inlet	32 50	79 44	-0 09	-0 16	-0.2	0.0	5.0	5.9	2.5
2567	Isle of Palms (outer coast)	32 47	79 47	-0 16	-0 17	0.0	0.0	5.2	6.1	2.6
2569	Sullivans Island (outer coast)	32 46	79 50	-0 15	-0 16	0.0	0.0	5.2	6.1	2.6
	Charleston Harbor									
2571	Entrance (north jetty)	32 44	79 48	-0 16	-0 19	0.0	0.0	5.2	6.1	2.6
2573	Fort Sumter	32 45	79 52	-0 09	-0 13	-0.2	0.0	5.0	5.9	2.5
2575	The Cove	32 46	79 52	-0 08	-0 06	-0.1	0.0	5.1	6.0	2.6
2577	CHARLESTON (Customhouse Wharf)	32 47	79 55	Daily predictions				5.2	6.1	2.6
2579	Shipyard Creek, 0.8 mile above entrance.	32 50	79 57	+0 27	+0 16	+0.1	0.0	5.3	6.3	2.6
	Cooper River									
2581	North Charleston	32 52	79 58	+0 40	+0 36	0.0	0.0	5.2	6.1	2.6
2583	Goose Creek entrance	32 54	79 57	+0 50	+0 40	0.0	0.0	5.2	6.1	2.6
2585	Yeamans Hall, Goose Creek	32 56	79 59	+2 36	+2 03	-0.2	0.0	5.0	5.9	2.5
2587	Snow Point, north of	32 57	79 56	+1 27	+1 14	-0.3	0.0	4.9	5.8	2.4
2589	Dean Hall	33 03	79 56	+2 46	+2 27	-1.1	0.0	4.1	4.8	2.0
2591	Quimby Creek, East Branch	33 06	79 49	+4 08	+3 47	-0.9	0.0	4.3	5.1	2.1
2593	RR. bridge, West Branch	33 06	79 57	+3 18	+3 05	-1.0	0.0	4.2	5.0	2.1
	Wando River									
2597	Cainhoy	32 55	79 50	+0 57	+0 39	+0.8	0.0	6.0	7.1	3.0
2599	Woodville	32 55	79 44	+2 07	+1 22	+1.1	0.0	6.3	7.4	3.2
	Ashley River									
2601	Wappoo Creek (highway bridge)	32 46	79 58	+0 22	+0 22	0.0	0.0	5.2	6.1	2.6
2603	Highway bridge	32 47	79 58	+0 22	+0 15	0.0	0.0	5.2	6.1	2.6
2605	Highway bridge (2 miles above)	32 50	79 58	+0 25	+0 17	+0.3	0.0	5.5	6.5	2.8
2607	Bees Ferry bridge	32 51	80 03	+1 14	+1 07	+0.3	0.0	5.5	6.4	2.8
2609	Magnolia Gardens	32 53	80 05	+1 16	+1 06	+0.4	0.0	5.6	6.6	2.8
2611	Greggs Landing	32 56	80 09	+1 47	+1 35	+0.9	0.0	6.1	7.2	3.0
	SOUTH CAROLINA, Outer Coast-Con.									
2613	Folly Island (outer coast)	32 39	79 56	-0 15	-0 18	0.0	0.0	5.2	6.1	2.6
2615	Folly River (below bridge)	32 39	79 58	+0 13	-0 09	+0.2	0.0	5.4	6.4	2.7
2617	Legareville, 1 mile above, Stono River	32 41	80 00	+0 13	+0 06	0.0	0.0	5.2	6.1	2.6
2619	Elliott Cut, Stono River	32 46	80 00	+0 48	+0 49	0.0	0.0	5.2	6.1	2.6
2621	Church Flats, RR. bridge, Stono River	32 45	80 08	+2 06	+1 47	+0.5	0.0	5.7	6.7	2.8
	North Edisto River									
2623	Rockville, Bohicket Creek	32 36	80 12	+0 20	+0 05	+0.6	0.0	5.8	6.8	2.9
2624	Point of Pines	32 35	80 14	+0 16	+0 11	+0.4	0.0	5.6	6.5	2.8
2625	Dawho River entrance	32 38	80 16	+0 46	+0 27	+0.9	0.0	6.1	7.2	3.0
2627	Dawho Ferry, Dawho River	32 38	80 20	+1 18	+1 00	+1.3	0.0	6.5	7.7	3.2
2629	Toogoodoo Creek, 2 miles above ent.	32 40	80 18	+1 11	+0 35	+1.2	0.0	6.4	7.6	3.2
2631	Yonges Island, Wadmalaw River	32 41	80 14	+1 19	+0 34	+1.4	0.0	6.6	7.8	3.3
2633	Ravens Point, Church Creek	32 42	80 09	+1 43	+0 49	+1.8	0.0	7.0	8.3	3.5
				on SAVANNAH RIVER ENT., p.100						
2635	Edisto Beach, Edisto Island	32 30	80 18	-0 35	-0 41	-1.0	0.0	5.9	6.9	2.9
	South Edisto River									
2637	Big Bay Creek entrance	32 30	80 20	0 00	-0 09	-0.8	0.0	6.1	7.2	3.0
2639	Peters Point, St. Pierre Creek	32 32	80 21	+0 17	+0 04	-0.7	0.0	6.2	7.3	3.1
2641	Watts Cut ent., 0.8 mile south of	32 36	80 23	+0 38	+0 55	-0.6	0.0	6.3	7.4	3.1
2643	Dawho River entrance	32 39	80 23	+1 28	+1 42	-0.6	0.0	6.3	7.4	3.1
2645	Jacksonboro	32 46	80 27	+3 16	+4 21	*0.28	*0.28	1.9	2.2	0.9

Endnotes can be found at the end of table 2.

Figure 24. Predicted tide at Charleston Harbor, South Carolina

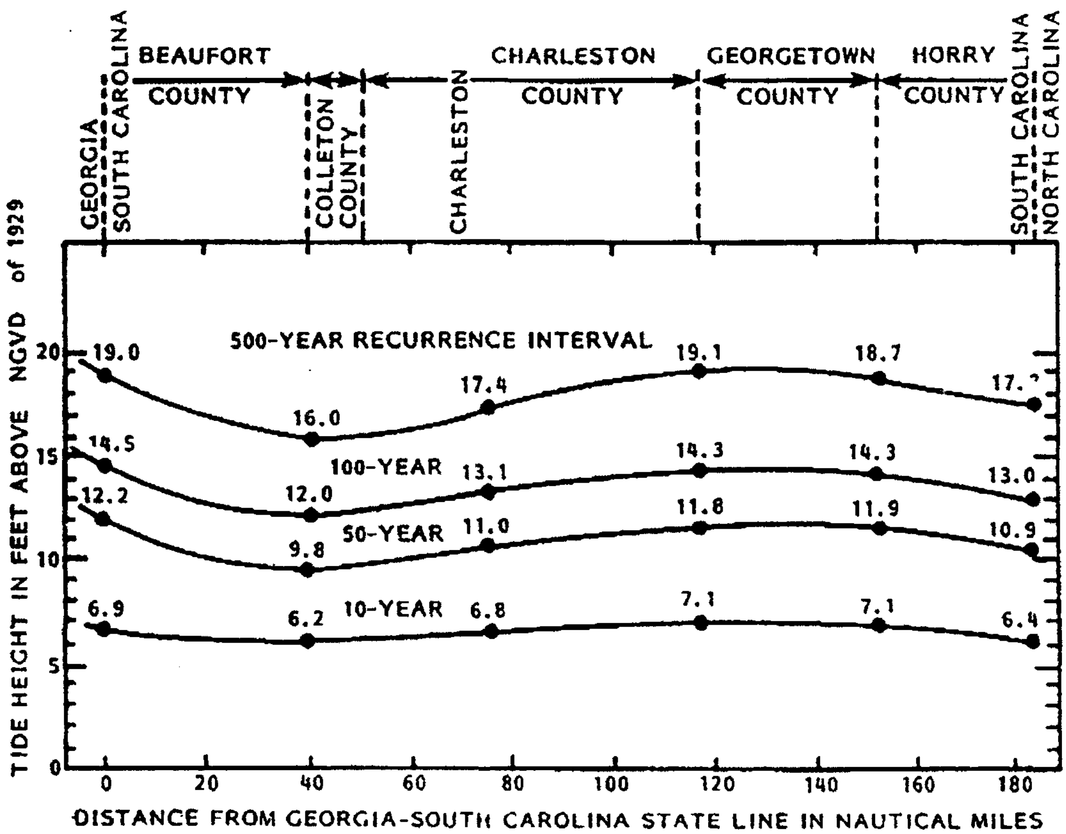

Figure 25. Storm-plus-tide stage-frequency curves on the open coast for South Carolina (Myers 1975)

7 Analysis for Multi-Inlet Systems

If a particular project can be significantly affected by storm-induced currents through multiple inlets, a variation in the procedure presented in previous chapters can be applied. In most cases, one inlet will dominate the hydraulics of a given system and the storm analysis procedure can be carried out as if the dominant inlet were an independent system. If insufficient knowledge is known about a given system, the following technique could be used to evaluate how to apply the present procedure.

As stated previously, two storm durations are determined from NOAA data and two surge hydrographs are developed for each known stage frequency. These hydrographs are convolved with tide at each of four specified phases to produce eight surge-plus-tide time series for running DYNLET1. The same boundary condition cannot be used to force two inlet entrances unless they are close together (for guidance, separated by a distance less than 1/2 R). The reason for this is that there is a phase lag between the inlet entrances if the storm is passing alongshore (the lag being a function of the forward speed of the storm). If the storm landfalls, the surge at one inlet entrance will dominate because it is closer to the storm center. One way to overcome this problem is to perform a preliminary analysis to determine what boundary conditions are best suited for conducting the velocity-frequency analysis procedure.

Using a similar analogy for the development of Equation 4 for surge as a function of time, Equation 3 can be used to show surge at a distance r from the storm's peak surge (usually at $r = R$)

$$S_r = S_o[1 - e^{-(R/r)}] \tag{6}$$

For example, if R is 33 n.m. and the inlets are 16.5 n.m. apart, an estimate of the peak surge, S_1, at the second inlet would be

$$S_1 = S_o(1 - e^{-2}) = 0.86S_o \tag{7}$$

or 86 percent of the peak surge, S_o, at inlet "o".

Program SSEL can be used to generate data for a given stage as described previously. SSEL can be run again to calculate a second set of data for a

stage which is 14 percent less (for the example above). The first of eight data sets in each of these two SSEL runs can be used as boundary conditions to DYNLET1 for a preliminary test. For notation, call these two time series B_0 and B_1 (the peak of B_1 is 86 percent of that for B_0). Here we assume the grid network provides for the complete representation of both adjacent inlets and how they connect to the project site.

The objective is to determine which inlet, if any, dominates the hydrodynamic regime at the project site. This can be done by running DYNLET1 twice, alternative use of B_0 and B_1 at the two inlets. A third run can be made where one assumes the peak stage occurs at the midpoint between the two inlets. In this case, Equation 6 can be used with r = 8.25 n.m. (following the same example above). Here we find that the peak surge at both inlets is 98 percent of the surge at the midpoint. In fact, as stated in the guidance given previously, simply run the same stage time series at both inlets. This preliminary test should be run for a reasonable size storm (say a 50- or 100-year return period stage).

The results from the three runs can be analyzed to reveal which case produces the largest flood and ebb current at the project site. Then the analysis procedure described in previous chapters could be carried out for the multiple inlet case by applying the same time series at both inlets or by applying the time series at one inlet or the other (decided from the above analysis) and reducing the peak surge at the other inlet according to Equation 6.

The procedure described above is probably conservative. However, another test could be run to look at a project site where storm passage alongshore dominates storm occurrence. In this case, the time series used at the first inlet (if on the east coast that would always be the southern-most inlet) would be lagged in phase for the second inlet by the distance between the inlets divided by the forward speed of the storm. Results from this test could be compared to the tests above to check the most conservative approach.

8 Summary

This report describes the process of applying DYNLET1 to a tidal inlet, specifically to Brunswick Harbor, Georgia, for the purpose of estimating tide and storm response at DOT project sites.

A primary DOT goal is to develop methodology for estimating frequency-indexed currents impacting bridges. DYNLET1 is an excellent model for computing storm currents precisely at bridge piers, however, a statistical procedure is needed to select what events to simulate and how the results should be analyzed to yield frequency of occurrence of storm-induced velocities.

The process of model application involves several steps including data acquisition, grid development, model validation, and storm application. In this report, data requirements for model validation as well as for storm simulations are presented. Typically, DYNLET1 is tidally-calibrated with field data to a specific project site. However, if historical storm surge data are available, a storm calibration is performed. Once calibrated, DYNLET1 is used to simulate the hydrodynamic response of the system to storm events. Storm hydrographs are used as input to DYNLET1 and model results are saved at critical locations (i.e., near a bridge pier). Velocities produced by the model are thus used to construct velocity-frequency curves for a specific area. This report covers the entire application process.

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Appendix A FORTRAN Listing for Program SSEL

```
C     PROGRAM SSEL
C     PROGRAM TO DEVELOP STORM HYDROGRAPHS FOR INPUT TO
C     DYNLET1 TO DETERMINE FREQUENCY-INDEXED CURRENTS
      DIMENSION TIME(801),TIDE(4,801),SURGE(2,801)
     1 ,RAD(2),SPD(2),YY1(801),YY2(801),YY3(801),DUR(2),
     1 TIDMID(4)
C     READ IN MAJOR DATA FOR SPECIFIC SITE
C     RAD = RADIUS TO MAX WINDS
C     SPD - FORWARD SPEED
C     DURATION IS COMPUTE AS A FUNCTION OF RAD AND SPD
C
C     STOT = TOTAL WATER ELEVATION FOR A SPECIFIC RETURN
C          PERIOD (OBTAINED FROM FEMA)
C     AMP = TIDAL AMPLITUDE FOR MEAN TIDE AT THE SITE
C     SEMID = 1 FOR A DIURNAL TIDE AND 2 FOR A SEMI-DIURNAL
C     DELT = DELTA T FOR TABULAR INPUT OF SURGE HYDROGRAPH
C          INTO DYNLET1
C     ********************************************************
C
C     READ DATA
      WRITE(*,*) 'ENTER 2 VALUES FOR STORM RADIUS TO MAXIMUM
     # WINDS IN NAUTICAL MILES: '
      READ(*,*) RAD(1),RAD(2)
      WRITE(*,*) 'ENTER 2 VALUES FOR STORM FORWARD SPEED IN
     # KNOTS:'
      READ(*,*) SPD(1),SPD(2)
      WRITE(*,*) 'ENTER THE SURGE + TIDE STAGE AT THE OCEAN
     # BOUNDARY IN FEET: '
      READ(*,*) STOT
      WRITE(*,*) 'ENTER THE AMPLITUDE OF THE MEAN TID AT THE
     # OCEAN BOUNDARY IN FEET: '
      READ(*,*) AMP
      WRITE(*,*) 'ENTER 1 FOR A DIURNAL TIDE AND 2 FOR A
     # SEMI-DIURNAL:'
      READ(*,*) SEMID
```

```
      WRITE(*,*) 'ENTER THE TIME INTERVAL IN HOURS FOR CREATING
     #THE INPUT STAGE TIME SERIES TO DYNLET1 (USUALLY .25 OR .5
     #HRS):'
      READ(*,*) DELT
C
      NEND=100./DELT+1.01
      NEND2=NEND/2+1
      NEND21=NEND2+1
      K=0
CC    J1 AND J2 DEFINE THAT PORTION OF THE COMBINED
CC    SURGE PLUS TIDE FILE CREATED BY THIS PROGRAM.
CC    THIS PROGRAM DEVELOPS 100 HOURS OF SURGE PLUS
CC    TIDE-YOU NEED ONLY SIMULATE FROM HOUR 30 TO
CC    70 TO CAPTURE PEAK FLOOD AND EBB CONDITIONS.
CC    THUS J1 AND J2 ARE SET THE APPROPRIATE TIME
CC    DIVIDED BY DELT +1
      J1=30./DELT + 1.01
      J2=70./DELT + 1.01
      PER = 12.42
      IF(SEMID .EQ. 1.0) PER = 24.84
      DUR(1)=RAD(1)/SPD(2)
      DUR(2)=RAD(2)/SPD(1)
      PI=3.141592654
      SHFT50=100*PI/PER
CC     COMPUTE TIDE AND SHIFT 50 HOURS
      DO 30 N=1,4
      DO 20 NN=1,NEND
      XN=NN-1
      PHASE=(PI/180.)*(N-1)*90.
      TIME(NN)=DELT*XN
   20 TIDE(N,NN)=AMP*COS(2.*PI*TIME(NN)/PER+PHASE-SHFT50)
   30 TIDMID(N)=TIDE(N,NEND2)
CC
CC     COMPUTE SURGE TABLES FOR DYNLET1 INPUT STORM
CC     HYDROGRAPHS
CC     THERE ARE 8 TABLES: COMBINATION OF 4 TIDE AND 2 STORMS
CC     YY3 = TOTAL ELEVATION - INPUT FOR DYNLET1
CC     YY1 = TIDE ; YY2 = SURGE -- AVAILABLE FOR PRINT/PLOT
CC
      OPEN(UNIT=10, FILE='SSEL.OUT')
      ISTM =1
      DO 9000 NTIDE=1,4
CC
CC     COMPUTE STORM SURGE
      DO 1000 N=1,2
      DUMT=0.
      SURGE(N,NEND2)=1.
```

```
      DO 1000 NN=NEND21,NEND
      DUMT=DUMT+DELT
      SURGE(N,NN)=(1.-EXP(-DUR(N)/DUMT))
 1000 SURGE(N,NEND+1-NN)=SURGE(N,NN)
CC
      SRGMLT=STOT-TIDMID(NTIDE)
      DO 9000 NSTRM=1,2
      DO 2000 NN=1,NEND
      SURGE(NSTRM,NN)=SURGE(NSTRM,NN)*SRGMLT
      YY3(NN)=TIDE(NTIDE,NN)+SURGE(NSTRM,NN)
 2000 CONTINUE
      YMAX=0.
      DO 3000 NN=1,NEND
      IF(YY3(NN).LT.YMAX) GO TO 3000
      YMAX=YY3(NN)
      NMAX=NN
 3000 CONTINUE
 3001 SURMUL=(STOT-TIDE(NTIDE,NMAX))/SURGE(NSTRM,NMAX)
      DO 4000 NN=1,NEND
      YY1(NN)=TIDE(NTIDE,NN)
      YY2(NN)=SURGE(NSTRM,NN)*SURMUL
      YY3(NN)=YY1(NN)+YY2(NN)
CC    INCLUDE AN OUTPUT STATEMENT IF NEEDED
CC     WRITE (    ) NN,TIME(NN),YY1(NN),YY2(NN),YY3(NN)
CC    OR INCLUDE A PLOT OF THE CURVES LATER
 4000 CONTINUE
      YMAX=0.0
      DO 5000 NN=1,NEND
      IF (YY3(NN).LT.YMAX) GO TO 5000
      YMAX=YY3(NN)
      NMAX=NN
 5000 CONTINUE
      IF (YMAX .GT. (STOT+0.001)) GO TO 3001
CC    WRITE AN EXTER.DAT FILE FOR DYNLET1
      WRITE (10,*) 'OUTPUT FILE FROM SSEL MODEL'
      WRITE (10,*) 'NUMBER OF TIMESTEPS'
      IDUM=J2-J1+1
      WRITE (10,*) IDUM
      WRITE (10,4001) (TIME(J),YY3(J),J=J1,J2)
 4001 FORMAT(8F10.5)
CC    J1 AND J2 ARE THAT PORTION OF THE CURVE TO MODEL
CC
CC    CALL A PLOT ROUTINE TO INSPECT RESULTS
CC
      WRITE(*,*) ISTM,' *STORM TIME SERIES HAS BEEN WRITTEN TO
FILE*'
      ISTM=ISTM+1
```

```
 9000 CONTINUE
CC    CALL ADDITIONAL PRINT OR PLOT ROUTINE
      STOP
      END
```

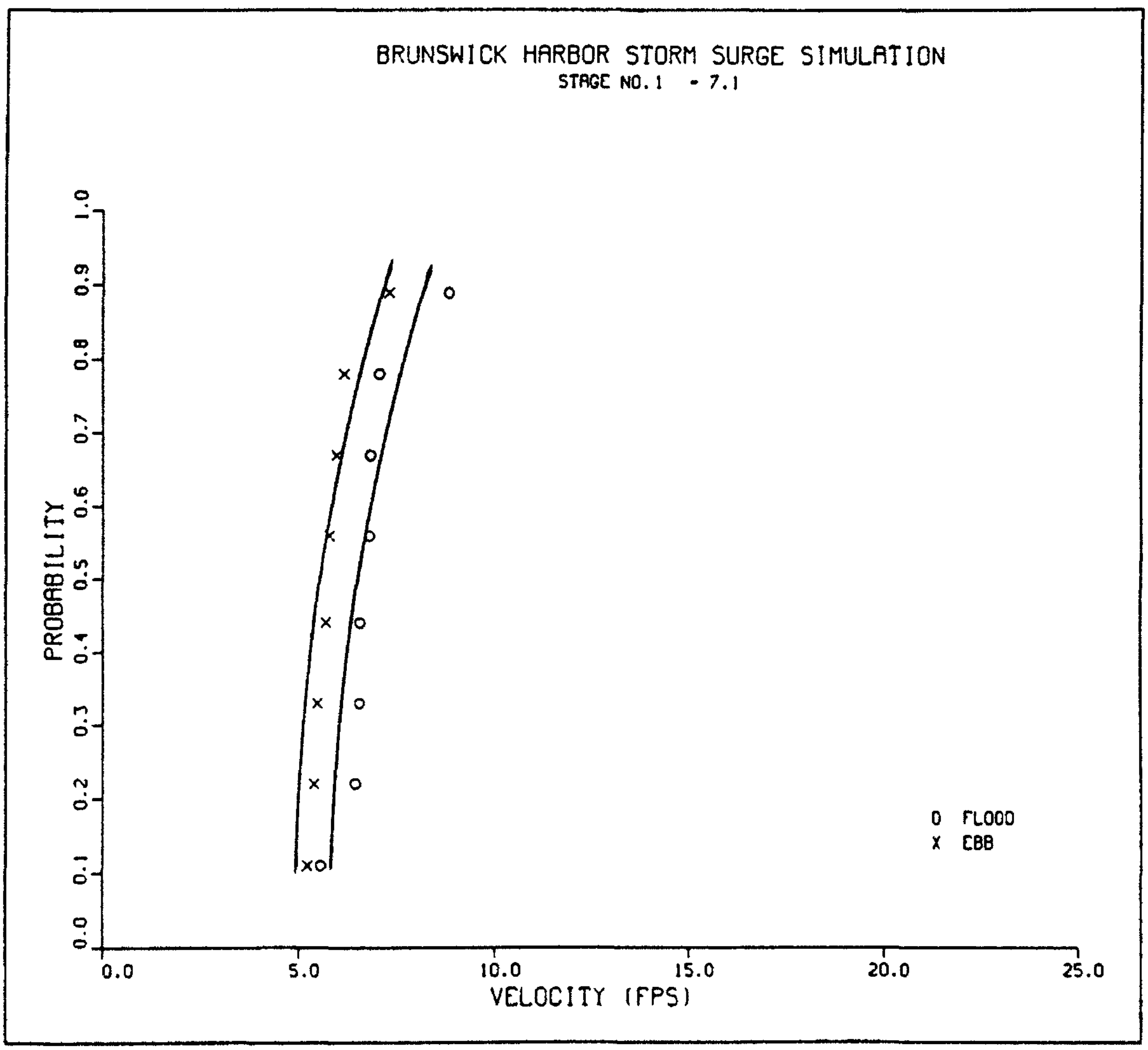
Appendix B FORTRAN Listing for Program VANAL

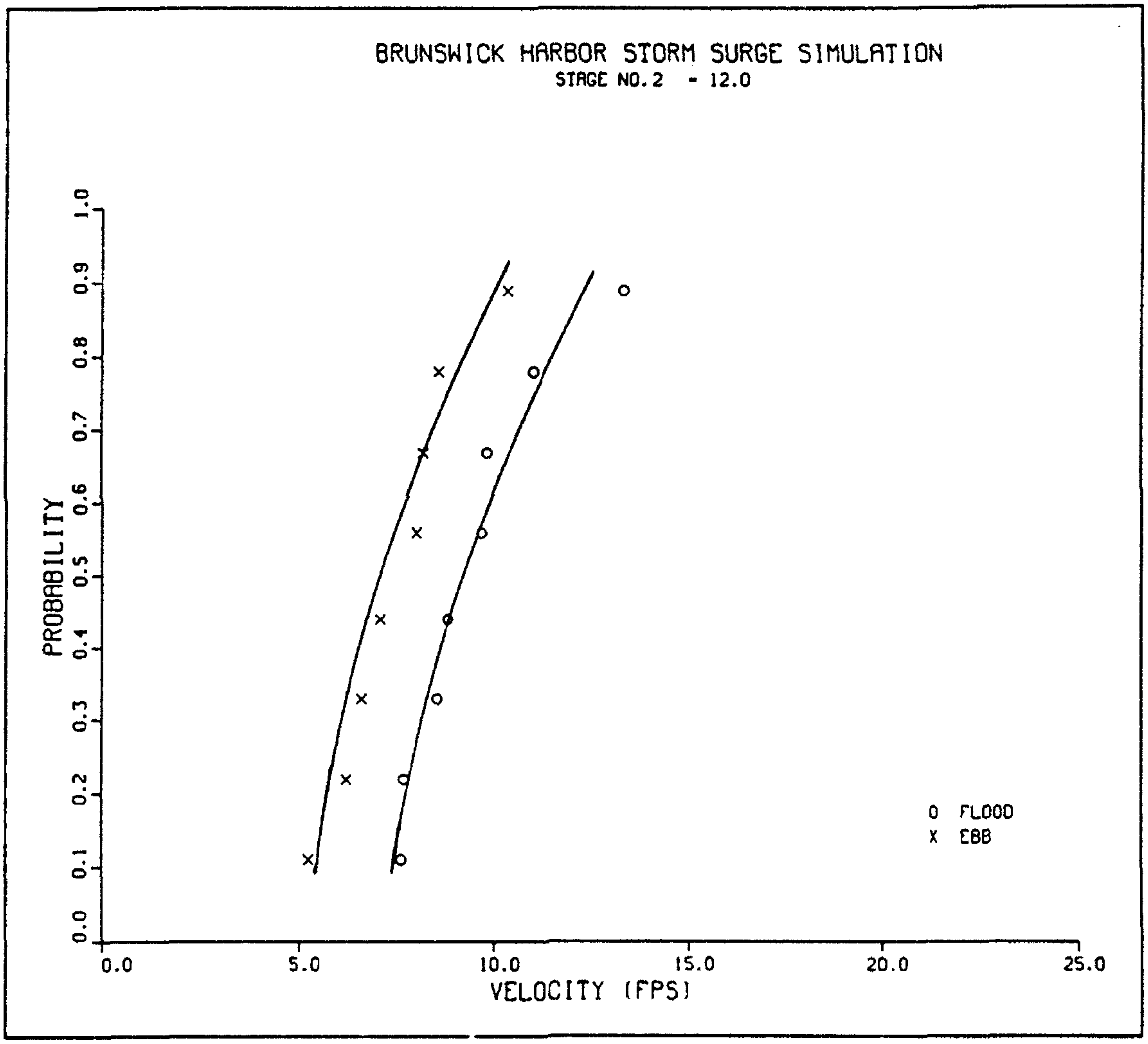
```
C     PROGRAM VANAL
C
C     CODE TO ANALYZE STORM-INDUCED VELOCITIES
C     ASSUMES EQUAL PROBABILITY FOR ALL STORM-TIDE
C     EVENTS SIMULATED AND APPLIES STANDARD WEIBULL
C     FORMULA TO GIVE PROBABILITY DISTRIBUTION
C
C     VANAL READS FILES PRODUCED BY DYNLET1 VIA VPLOT
C     ROUTINE--NAMELY, FILES OF VELOCITY TIME SERIES
C     AT POINTS WHERE FREQUENCY-INDEXED VELOCITIES ARE
C     NEEDED.
C
      DIMENSION VELFLD(8,20),VELEBB(8,20),PROB(8)
      DIMENSION STAGE (10)
C     HANDLES A LIMIT OF 20 GAGES FOR VELOCITY OUTPUT
      DIMENSION V(200,20)
      OPEN (UNIT=10, FILE='VTOTAL.DAT')
      OPEN (UNIT=11, FILE='VANAL.OUT')
CC       READ DATA FROM SCREEN
      WRITE (*,*) ' ENTER NUMBER OF VELOCITY GAGE POINTS:  '
      READ (*,*) NVELPTS
      WRITE (*,*) ' ENTER LENGTH OF VELOCITY TIME SERIES:  '
      READ (*,*) NVL
      WRITE (*,*) ' ENTER NUMBER OF STAGES TO ANALYZE:  '
111      READ (*,*) NSTAGE
         IF(NSTAGE.GT.10) THEN
           WRITE(*,*) 'MAXIMUM NUMBER OF STAGES TO
     #ANALYZE IS 10'
           GO TO 111
         END IF
      WRITE (*,*)  ' ENTER VALUES FOR EACH STAGE:  '
      READ(*,*) (STAGE(I),I=1,NSTAGE)
```

```
CC
CC    SET INVARIANTS--PROGRAM SET FOR 8 EVENTS (2 STORMS
CC                                   X 4 TIDES)
      NEVENT=8
      XNEVENT=8.
C     SET PROBABILITY ACCORDING TO WEIBULL FOR 8 EVENTS
C                                     (M/9)
      DO 2 N=1,NEVENT
      XN=N
    2 PROB(N)=XN/(1.+XNEVENT)*100.
CC
C     MAJOR LOOP OVER THE NUMBER OF STAGES TO READ AND
C     ANALYZE 8 STORM TIDE EVENTS FOR EACH STAGE
      DO 100 NS=1,NSTAGE
CC      READ VELOCITY FILES FROM DYNLET1--ASSUME FILES
CC      HAVE BEEN CREATED BY RUNNING 8 DYNLET1
CC      SIMULATIONS FOR EACH STAGE
       DO 1000 N=1,NEVENT
CC      READ VELOCITY TIME SERIES FOR EACH GAGE POINT

       READ(10,*)
       READ(10,*)
       DO 101 I = 1,NVL
       READ (10,99) (IDUM1,IDUM2,V(I,NV),NV=1,NVELPTS)


   98   FORMAT (I5,I7,I11,4X,F10.2)
   99   FORMAT (10X,I7,I11,4X,F10.2)
  101   CONTINUE
C
CC      DETERMINE MAX AND MIN IN VELOCITY FOR EACH EVENT
CC      (N) AND EACH VELOCITY GAGE POINT (NV)
       DO 1001 NV = 1,NVELPTS
       VELFLD(N,NV)=0.
       VELEBB(N,NV)=0.
       DO 1002 I =1,NVL
       IF (VELFLD(N,NV) .LT. V(I,NV)) VELFLD(N,NV)=V(I,NV)
       IF (V(I,NV) .LT. VELEBB(N,NV)) VELEBB(N,NV)=V(I,NV)

 1002   CONTINUE
 1001   CONTINUE

 1000   CONTINUE
C
C     DETERMINE RANK FOR NEXT GAGE POINT FOR 8 EVENTS
      DO 500 NV=1,NVELPTS
```

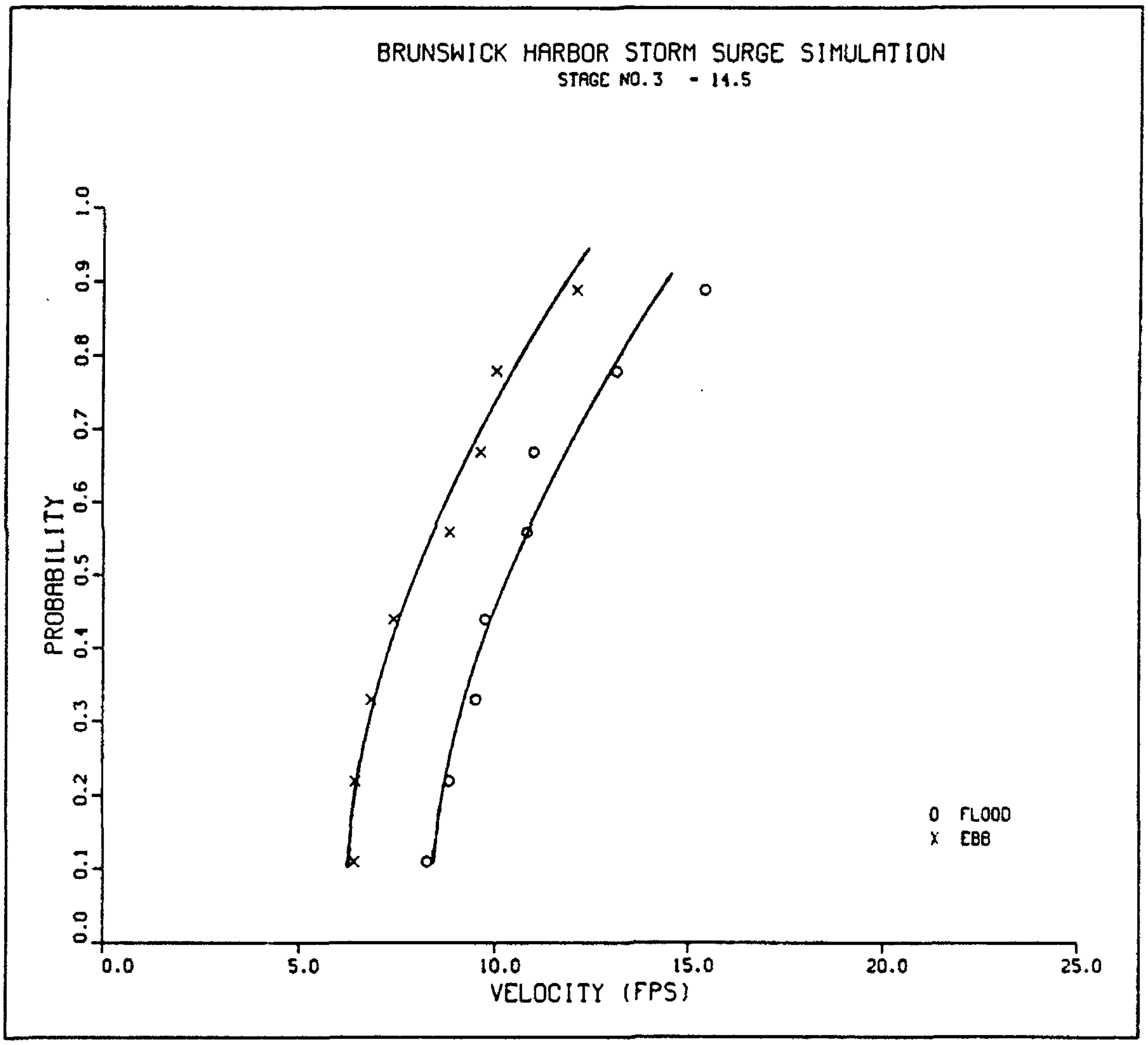
```
      CALL INSSORT (VELFLD,NEVENT)
      CALL INSSORT (VELEBB,NEVENT)
      WRITE (11,4) NS,STAGE(NS),NV
   4  FORMAT (' STAGE ',I2,' = ',F10.5,' FT
     #FOR GAGE POINT NO.',I2/
     # ' RANK  VEL FLD  VEL EBB   PROB')
      DO 1005 N=1,NEVENT
      WRITE (11,3) N, VELFLD(N,NV), VELEBB(NEVENT-N+1,NV),
     #          PROB(N)
 1005 CONTINUE
   3  FORMAT (3X,I2,3X,2(F7.2,2X),F5.0)
  500 CONTINUE
  100 CONTINUE
      STOP
      END
       SUBROUTINE INSSORT (X,N)
       IMPLICIT NONE
C       SORT X(N) IN ASCENDING ORDER
       INTEGER N
       REAL X(N)
       REAL XX
       INTEGER I,J
       DO 1 J=2,N
         XX=X(J)
         DO 2 I=J-1,1,-1
           IF (X(I) .LE. XX) GO TO 3
           X(I+1) = X(I)
   2     CONTINUE
         I = 0
   3     X(I+1) = XX
   1   CONTINUE
       RETURN
       END
```

Appendix C Miscellaneous Brunswick Harbor Results

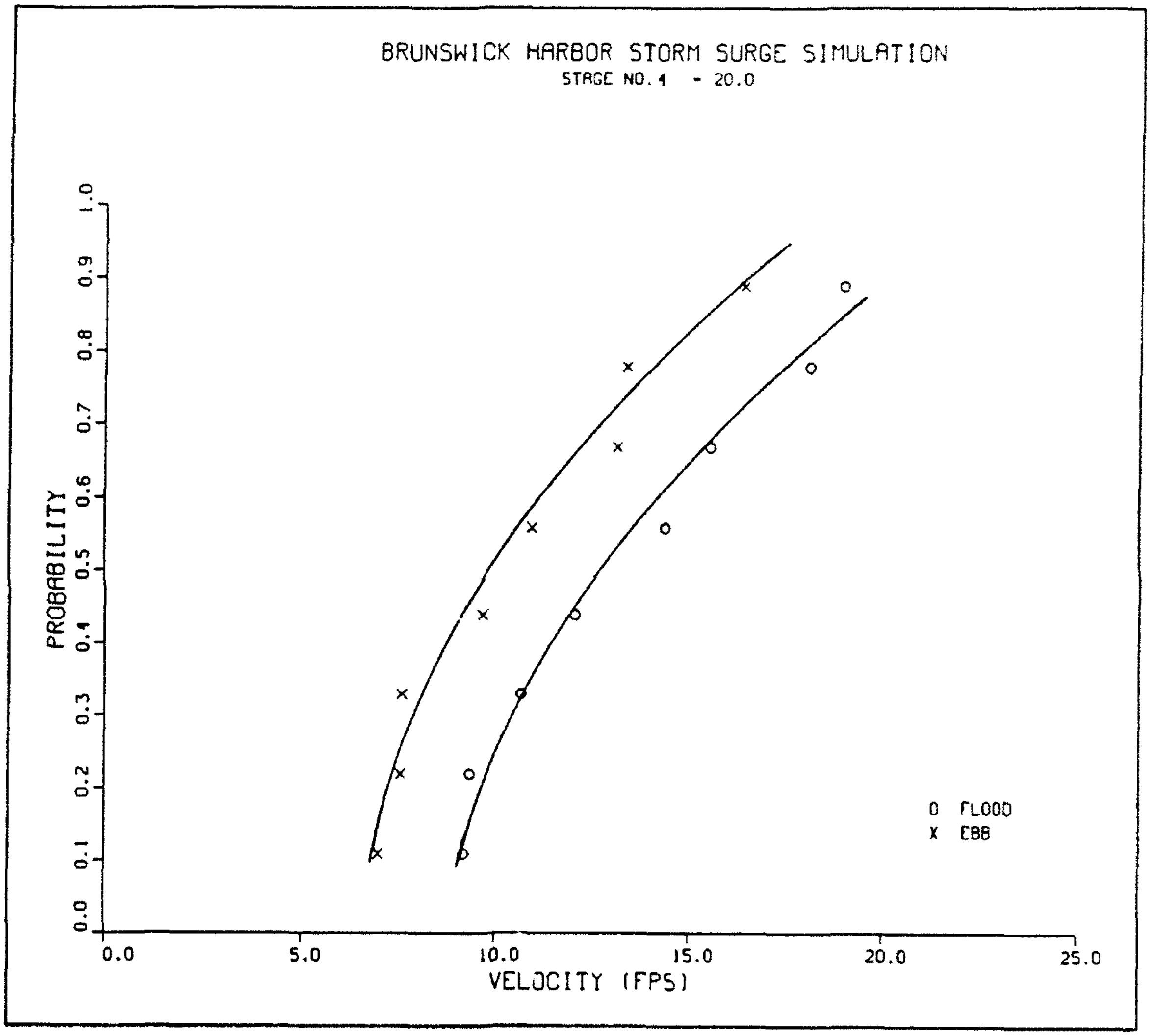


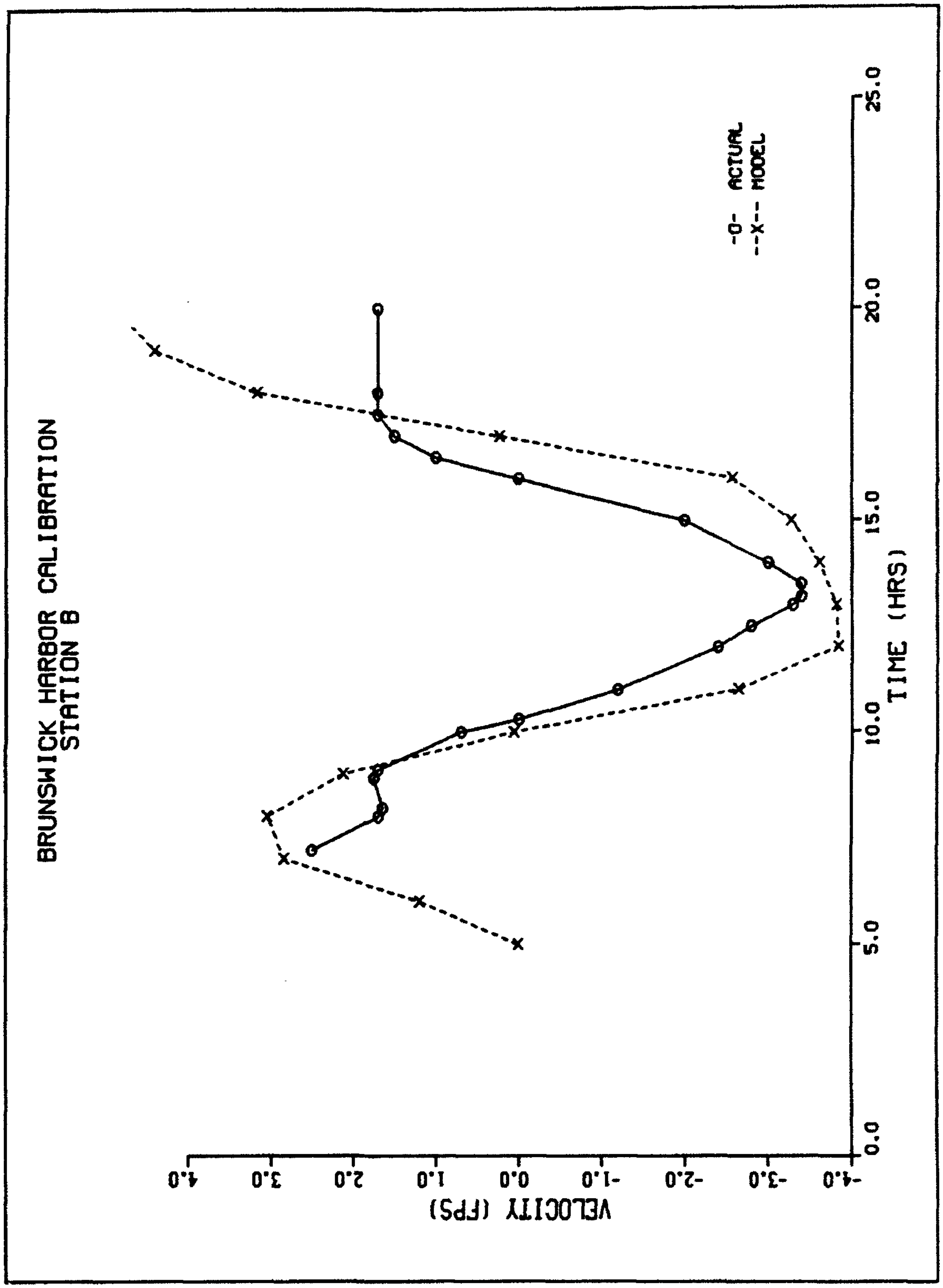


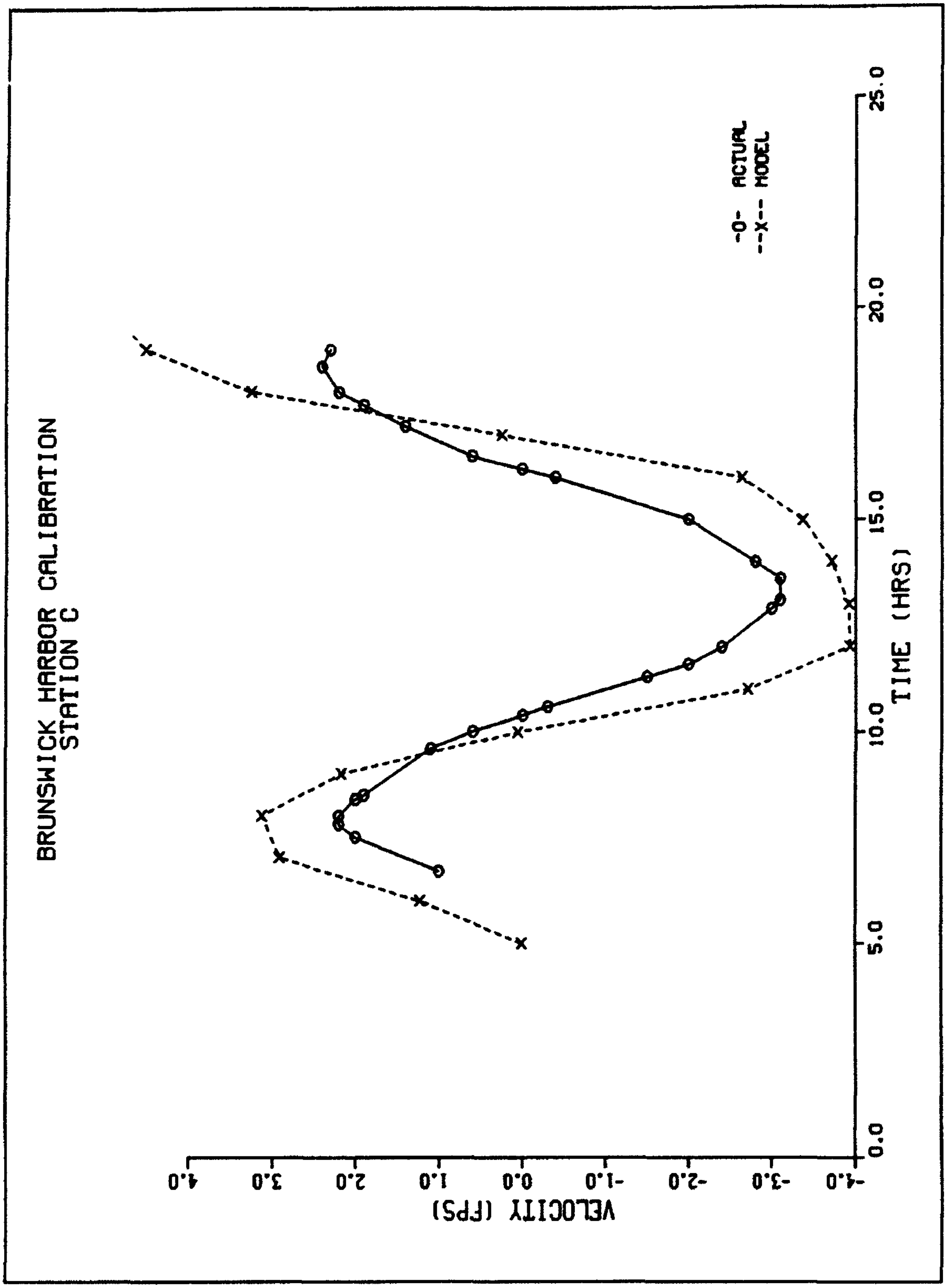
BRUNSWICK HARBOR STORM SURGE SIMULATION
STAGE NO. 2 - 12.0
PROBABILITY
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.0
5.0
10.0
15.0
20.0
25.0
VELOCITY (FPS)
O FLOOD
X EBB



BRUNSWICK HARBOR STORM SURGE SIMULATION
STAGE NO. 3 - 14.5
PROBABILITY
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.0
5.0
10.0
15.0
20.0
25.0
VELOCITY (FPS)
O FLOOD
X EBB


BRUNSWICK HARBOR STORM SURGE SIMULATION
STAGE NO. 4 - 20.0
PROBABILITY
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.0
5.0
10.0
15.0
20.0
25.0
VELOCITY (FPS)
O FLOOD
X EBB


BRUNSWICK HARBOR CALIBRATION
STATION B
-O- ACTUAL
--X-- MODEL
TIME (HRS)
VELOCITY (FPS)
0.0
5.0
10.0
15.0
20.0
25.0
-4.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0



BRUNSWICK HARBOR CALIBRATION
STATION C
-O- ACTUAL
--X-- MODEL
TIME (HRS)
VELOCITY (FPS)
0.0
5.0
10.0
15.0
20.0
25.0
-4.0
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
4.0

Appendix D
DYNLET1 Input Data Files for Brunswick Harbor

START.DAT file

```
* * * * * * * * * * * * * Brunswick  Harbor
* * * * * * * * * * * * * Georgia
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
* * * * * * * * * * * * * * *
**************************************************
* START.DAT created on 01/04/1993 at 18:33.
**************************************************
A   General Parameters
**************************************************
A.1  T0     Tfin    yeps     Qeps     theta    N    IWIND
     6.00   21.00    0.05   200.00     1.00   43     0
A.2  Units
ENGLISH
A.3  Unit of Distance
FEET
**************************************************
B   Channels, Junctions and External Boundary Nodes
**************************************************
B.1  # Channels, # Junctions, # Boundary Nodes
       3         1          3
```

B.2 Channel Descriptions Channel No. Start End

1	1	13
2	14	24
3	25	43

B.3 Junction Number Nodes

1	3	13	14	25

B.4 Boundary Point Node ID Parameters

1	1	1
2	24	2
3	43	2

****

C Computational Parameters

****

C.1 Computation time step in seconds

1800.00

C.2 Maximum Iterations per time step

10

C.3 Number of printout times

16

C.4 Print times in hours

6.00	7.00	8.00	9.00	10.00	11.00	12.00	13.00
14.00	15.00	16.0	17.0	18.0	19.00	20.0	21.0

C.5 Number of output stations

43

C.6 Output Stations

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40
41	42	43					

****

D Node Parameters

****

D.1 Node Distances

0.0	7333.0	16166.0	20433.0	25433.0	29933.0
34600.0	39433.0	43933.0	46433.0	48933.0	51933.0
55600.0	55600.0	59933.0	62433.0	64933.0	67433.0
70100.0	72600.0	75600.0	80600.0	85933.0	100000.0
55600.0	60600.0	65767.0	70767.0	73267.0	75767.0
80767.0	83267.0	84533.0	84733.0	84833.0	85033.0
86033.0	88543.0	91043.0	93867.0	101710.0	106700.0
121000.0					

D.2 X Coordinates

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

D.3 Y Coordinates

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

D.4 Lateral Inflow

0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0					

D.5 Reference Elevations

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

D.6 Channel Alignment Angles

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

D.7 Transition Loss Coefficients

0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00					

D.8 Initial Water Level

5.0	5.0	5.0	5.0	5.0	5.0
5.0	5.0	5.0	5.0	5.0	5.0
5.0	5.0	5.0	5.0	5.0	5.0
5.0	5.0	5.0	5.0	5.0	5.0
5.0	5.0	5.0	5.0	5.0	5.0
5.0	5.0	5.0	5.0	5.0	5.0
5.0	5.0	5.0	5.0	5.0	5.0
5.0					

D.9 Initial Discharge

0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0
0.0					

SECTION.DAT file

```
*****************************************************
E   Cross Section Geometry and Friction Coefficients
*****************************************************
E.1 Node   Number of Elev Pts
    1      11
E.2 Stations and Elevations
       0.00   -24.00    3333.30   -25.00    6666.70   -26.00
   10000.00   -27.00   13333.30   -29.00   16666.70   -29.00
   18333.30   -30.00   20000.00   -32.00   21666.60   -30.00
   22500.00   -29.00   23333.30   -30.00
E.3 Mannings Coefficient at each station
     0.0250   0.0250   0.0250   0.0250   0.0250   0.0250
     0.0250   0.0250   0.0250   0.0250   0.0250
E.1 Node   Number of Elev Pts
    2      16
E.2 Stations and Elevations
       0.00   -22.00    3333.30   -23.00    6666.70   -23.00
   10000.00   -29.00   13333.30   -30.00   15333.30   -32.00
   16666.70   -32.00   19000.00   -33.00   21333.30   -34.00
   23333.30   -33.00   26666.60   -28.00   28666.60   -30.00
   31000.00   -31.00   36666.60   -36.00   37333.30   -35.00
   39000.00   -30.00
E.3 Mannings Coefficient at each station
     0.0250   0.0250   0.0250   0.0250   0.0250   0.0250
     0.0250   0.0250   0.0250   0.0250   0.0250   0.0250
     0.0250   0.0250   0.0250   0.0250
E.1 Node   Number of Elev Pts
    3      17
E.2 Stations and Elevations
       0.00   -16.00    6666.70   -16.00   10000.00   -15.00
   13333.30   -19.00   16666.70   -32.00   17333.30   -18.00
   18333.30   -17.00   20000.00   -18.00   23333.30   -26.00
   25000.00   -29.00   26333.30   -30.00   27666.60   -32.00
   29166.60   -30.00   32166.60   -32.00   34500.00   -30.00
   36666.60   -29.00   38333.30   -28.00
E.3 Mannings Coefficient at each station
     0.0250   0.0250   0.0250   0.0250   0.0250   0.0250
     0.0250   0.0250   0.0250   0.0250   0.0250   0.0250
     0.0250   0.0250   0.0250   0.0250   0.0250
E.1 Node   Number of Elev Pts
    4      19
```

E.2 Stations and Elevations

0.00	-10.00	4000.00	-10.00	5000.00	-14.00
6666.70	-15.00	9000.00	-12.00	9666.70	-6.00
11666.70	-9.00	13333.30	-12.00	13833.30	-18.00
15000.00	-21.00	16666.70	-32.00	18333.30	-12.00
20000.00	-12.00	22166.60	-18.00	23333.30	-21.00
26666.60	-26.00	28333.30	-29.00	33333.30	-30.00
37666.60	-28.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250					

E.1 Node Number of Elev Pts

5 24

E.2 Stations and Elevations

0.00	-5.00	333.30	-6.00	1666.70	-10.00
4000.00	-12.00	5000.00	-15.00	6666.70	-12.00
9333.30	-14.00	11666.70	-7.00	13500.00	-12.00
14333.30	-14.00	15333.30	-12.00	16666.70	-32.00
17000.00	-18.00	17166.60	-12.00	17400.00	-6.00
17833.30	-3.00	18166.60	-6.00	19333.30	-10.00
21000.00	-12.00	22166.60	-15.00	24000.00	-18.00
25333.30	-21.00	29333.30	-24.00	36666.60	-24.00

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250

E.1 Node Number of Elev Pts

6 22

E.2 Stations and Elevations

0.00	-7.00	1666.70	-12.00	3333.30	-6.00
4666.70	-6.00	5333.30	-7.00	6000.00	-6.00
6666.70	-7.00	8666.70	-12.00	12666.70	-12.00
14000.00	-13.00	15000.00	-15.00	16166.70	-18.00
16666.70	-32.00	17333.30	-18.00	17666.60	-12.00
18833.30	-6.00	20000.00	-6.00	21000.00	-12.00
23666.60	-18.00	27333.30	-20.00	30000.00	-19.00
34666.60	-20.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250		

E.1 Node Number of Elev Pts

7	30

E.2 Stations and Elevations

0.00	-3.00	3333.30	-6.00	3833.30	-8.00
9333.30	-10.00	12666.70	-8.00	13333.30	-12.00
15333.30	-16.00	16066.70	-18.00	16666.70	-32.00
17000.00	-30.00	17033.30	-24.00	17066.60	-18.00
17100.00	-12.00	17133.30	-6.00	17333.30	-4.00
17833.30	-6.00	18333.30	-8.00	19333.30	-6.00
20000.00	-6.00	21266.60	-8.00	21666.60	-5.00
22166.60	-4.00	22500.00	-4.00	24000.00	-12.00
25000.00	-13.00	26666.60	-16.00	29333.30	-15.00
33333.30	-13.00	35000.00	-13.00	38333.30	-12.00

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250

E.1 Node Number of Elev Pts

8	26

E.2 Stations and Elevations

0.00	-5.00	6666.70	-5.00	7000.00	-6.00
8333.30	-11.00	10000.00	-6.00	10833.30	-5.00
11666.70	-6.00	13666.70	-12.00	16000.00	-18.00
16666.70	-32.00	17066.60	-30.00	17800.00	-24.00
17866.60	-18.00	17933.30	-6.00	18000.00	-1.00
20333.30	-3.00	21333.30	-10.00	21833.30	-3.00
22166.60	-6.00	23000.00	-10.00	24000.00	-6.00
25000.00	-3.00	27000.00	-12.00	28333.30	-15.00
29666.60	-12.00	33333.30	-10.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

9	37

E.2 Stations and Elevations

0.00	4.00	3333.30	0.00	3666.70	-0.50
4666.70	-4.00	7000.00	-7.00	9166.70	-5.00
12000.00	-6.00	13000.00	-6.00	14333.30	-5.00
16000.00	-6.00	17000.00	-10.00	18000.00	-12.00
18333.30	-18.00	19333.30	-29.00	20000.00	-36.00
20833.30	-18.00	21000.00	-12.00	21333.30	-11.00

22000.00	-12.00	23333.30	-11.00	24166.60	-6.00
24333.30	0.00	24500.00	1.00	24666.60	0.00
25333.30	-4.00	26166.60	-6.00	27000.00	-11.00
27666.60	-6.00	28000.00	0.00	28333.30	1.00
28666.60	0.00	29333.30	-12.00	30333.30	-6.00
30666.60	-6.00	32000.00	-8.00	33000.00	-6.00
35500.00	-6.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250					

E.1 Node Number of Elev Pts

10 37

E.2 Stations and Elevations

0.00	4.00	2666.70	0.00	3333.30	-0.50
4666.70	-4.00	6666.70	-7.00	9666.70	-5.00
12000.00	-6.00	12666.70	-10.00	13333.30	-6.00
14666.70	-4.00	16000.00	-7.00	17000.00	-6.00
17666.60	-10.00	18000.00	-6.00	18333.30	-1.00
18600.00	-6.00	18666.60	-12.00	18800.00	-18.00
19000.00	-24.00	19333.30	-52.00	20333.30	-40.00
21000.00	-22.00	21333.30	-18.00	21566.60	-12.00
22000.00	-10.00	22666.60	-12.00	23000.00	-16.00
23266.60	-12.00	23333.30	-6.00	23366.60	-0.50
23666.60	-0.50	24333.30	-1.00	25000.00	-6.00
25333.30	-6.00	25666.60	-0.50	27000.00	0.00
28333.30	4.00				

E.3 Mannings Coefficient at each station

0.1200	0.1200	0.1200	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.1200
0.1200	0.0250	0.0250	0.0250	0.1200	0.0250
0.0250					

E.1 Node Number of Elev Pts

11 25

E.2 Stations and Elevations

0.00	0.00	1166.70	-0.50	3333.30	-5.00
10000.00	-6.00	10333.30	-7.00	10666.70	-6.00
11500.00	-6.00	12000.00	-10.00	12500.00	-6.00
14166.70	-1.00	15333.30	-0.50	15666.70	-6.00
15866.70	-12.00	16066.70	-18.00	16666.70	-43.00
17333.30	-60.00	18333.30	-21.00	18800.00	-18.00

19066.60	-12.00	19200.00	-6.00	19233.30	-0.50
19500.00	-0.50	19666.60	-1.00	20000.00	-0.50
20333.30	0.00				

E.3 Mannings Coefficient at each station

0.1200	0.1200	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.1200	0.1200	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.1200	0.1200	0.1200	0.0250
0.0250					

E.1 Node Number of Elev Pts

12 21

E.2 Stations and Elevations

0.00	4.00	1500.00	0.00	2000.00	-0.50
3333.30	-4.00	5333.30	-4.00	6133.30	-0.50
7066.70	-0.50	7666.70	-2.00	8166.70	-6.00
8500.00	-12.00	8666.70	-18.00	9166.70	-20.00
10000.00	-53.00	10666.70	-68.00	12266.70	-24.00
12300.00	-18.00	12333.30	-12.00	12400.00	-6.00
12466.70	-0.50	12600.00	0.00	13000.00	4.00

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250			

E.1 Node Number of Elev Pts

13 16

E.2 Stations and Elevations

0.00	4.00	2600.00	0.00	2900.00	-0.50
3100.00	-6.00	3200.00	-12.00	3333.30	-18.00
5000.00	-33.00	6666.70	-42.00	7666.70	-36.00
8000.00	-24.00	8033.30	-18.00	8066.70	-12.00
8100.00	-6.00	8133.30	-0.50	8566.70	0.00
10000.00	4.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250		

E.1 Node Number of Elev Pts

14 16

E.2 Stations and Elevations

0.00	4.00	2600.00	0.00	2900.00	-0.50
3100.00	-6.00	3200.00	-12.00	3333.30	-18.00
5000.00	-33.00	6666.70	-42.00	7666.70	-36.00
8000.00	-24.00	8033.30	-18.00	8066.70	-12.00
8100.00	-6.00	8133.30	-0.50	8566.70	0.00
10000.00	4.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250		

E.1 Node Number of Elev Pts

15 20

E.2 Stations and Elevations

0.00	0.50	3333.30	0.50	4666.70	0.00
6266.70	-0.50	6333.30	-1.00	6833.30	-4.00
8333.30	-2.00	8933.30	-6.00	9333.30	-12.00
9900.00	-18.00	10000.00	-19.00	10433.30	-18.00
11066.70	-18.00	11666.70	-22.00	12200.00	-18.00
12400.00	-12.00	12833.30	-6.00	13066.70	-0.50
13333.30	0.00	13666.70	4.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

16 28

E.2 Stations and Elevations

0.00	0.50	1733.30	0.00	2166.70	-6.00
2266.70	-12.00	2300.00	-13.00	2333.30	0.00
3000.00	0.50	5666.70	0.00	5766.70	-0.50
6000.00	-22.00	6066.70	-0.50	7333.30	-0.50
8000.00	-2.00	8266.70	-6.00	8466.70	-12.00
8666.70	-18.00	10066.70	-18.00	10733.30	-12.00
10800.00	-6.00	10866.70	-0.50	11000.00	-6.00
11666.70	-10.00	12333.30	-6.00	13100.00	-0.50
13233.30	0.00	15000.00	0.50	17833.30	0.00
19666.60	4.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250		

E.1 Node Number of Elev Pts

17 20

E.2 Stations and Elevations

0.00	0.50	6900.00	0.00	7000.00	-0.50
7400.00	-6.00	7833.30	-12.00	8166.70	-18.00
8333.30	-18.00	8733.30	-12.00	9000.00	-7.00
9500.00	-12.00	9766.70	-12.00	10233.30	-6.00
10333.30	-5.00	11000.00	-3.00	11266.70	-6.00
11666.70	-10.00	12600.00	-6.00	13066.70	-0.50
13666.70	0.00	16666.70	2.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

18 33

E.2 Stations and Elevations

0.00	0.50	4500.00	0.50	4533.30	0.00
4566.70	-6.00	4600.00	-12.00	5500.00	-18.00
6000.00	-30.00	6500.00	-18.00	6666.70	-12.00
6733.30	-6.00	6833.30	-0.50	7066.70	0.00
7500.00	0.50	8166.70	0.00	8666.70	-0.50
9266.70	-6.00	9333.30	-12.00	9366.70	-18.00
9833.30	-20.00	10266.70	-18.00	10500.00	-12.00
10666.70	-6.00	11000.00	-0.50	11933.30	-0.50
12066.70	-6.00	12333.30	-10.00	12500.00	-12.00
13166.70	-12.00	13733.30	-6.00	14066.70	-0.50
14500.00	0.00	17333.30	0.50	17533.30	4.00

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250			

E.1 Node Number of Elev Pts

19 38

E.2 Stations and Elevations

0.00	0.50	2333.30	0.00	2666.70	-3.00
2800.00	-3.00	2866.70	0.00	4000.00	0.50
4066.70	4.00	4133.30	0.50	6000.00	0.00
6200.00	-12.00	6266.70	-18.00	6400.00	-20.00
6533.30	-18.00	6800.00	0.00	7000.00	0.50
7133.30	0.00	7166.70	-6.00	7333.30	-9.00
7666.70	-6.00	7833.30	0.00	8000.00	0.50
9666.70	0.50	9833.30	0.00	10000.00	-18.00
10333.30	-26.00	10733.30	-12.00	11000.00	-0.50
11600.00	0.00	12500.00	0.50	13066.70	0.00
13200.00	-0.50	14000.00	-12.00	14333.30	-14.00
14500.00	-12.00	15066.70	-0.50	15266.70	0.00
23666.60	0.50	25000.00	4.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

20 38

E.2 Stations and Elevations

0.00	0.50	1000.00	0.50	1166.70	0.00
1266.70	-6.00	1666.70	-7.00	1933.30	-6.00
2066.70	0.00	3333.30	0.50	6666.70	0.00
7333.30	0.00	7400.00	-6.00	7666.70	0.00
8000.00	-38.00	8266.70	0.00	10000.00	0.50
11000.00	0.50	11200.00	4.00	11600.00	0.50
12166.70	0.00	12333.30	-0.50	12400.00	-6.00
12533.30	-12.00	12733.30	-18.00	13333.30	-23.00
13533.30	-18.00	13733.30	-0.50	13833.30	0.00
15000.00	0.50	16066.70	0.50	16100.00	0.00
16133.30	-6.00	16800.00	-12.00	17066.60	-14.00
17266.60	-12.00	17466.60	-6.00	17833.30	-0.50
20000.00	0.50	23666.60	4.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

21 33

E.2 Stations and Elevations

9.00	0.50	666.70	0.50	733.30	0.00
833.30	-6.00	1166.70	-9.00	1466.70	-6.00
1633.30	0.00	1666.70	0.50	8000.00	0.50
8166.70	0.00	8266.70	-6.00	8400.00	-20.00
8533.30	0.00	8666.70	0.50	12400.00	0.50
12433.30	0.00	12600.00	-6.00	12733.30	-12.00
13166.70	-15.00	13333.30	-15.00	13600.00	-6.00
13700.00	0.00	13733.30	0.50	16500.00	0.50
16533.30	0.00	16666.70	-0.50	16866.60	-12.00
17133.30	-18.00	17333.30	-30.00	17666.60	-18.00
17866.60	0.00	17900.00	0.50	19000.00	4.00

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250			

E.1 Node Number of Elev Pts

22 26

E.2 Stations and Elevations

0.00	0.50	1666.70	0.50	1700.00	0.00
1800.00	-6.00	2166.70	-11.00	2400.00	-6.00
2600.00	0.00	2666.70	0.50	5800.00	0.50
5833.30	0.00	5933.30	-5.00	5966.70	0.00
6000.00	0.50	11600.00	0.50	11633.30	0.00
11733.30	-6.00	12066.70	-12.00	12500.00	-17.00
12900.00	-12.00	13333.30	-10.00	14000.00	-12.00
14266.70	-6.00	14666.70	-0.50	14866.70	0.00
15000.00	0.50	21000.00	4.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

23 31

E.2 Stations and Elevations

0.00	0.50	3133.30	0.50	3166.70	0.00
3266.70	-5.00	3333.30	-12.00	4333.30	-12.00
4666.70	0.00	4733.30	0.50	9266.70	0.50
9300.00	0.00	9400.00	-0.50	9600.00	-12.00
9733.30	-18.00	10000.00	-35.00	10333.30	-18.00
10466.70	-12.00	10600.00	0.00	10666.70	0.50
13600.00	0.50	13666.70	0.00	14166.70	-12.00
14933.00	0.00	15000.00	0.50	15500.00	0.50
15533.30	0.00	15666.70	-6.00	15866.70	-13.00
16233.30	-0.50	16333.30	0.00	16400.00	0.50
25166.60	0.50				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250					

E.1 Node Number of Elev Pts

24 31

E.2 Stations and Elevations

0.00	0.50	3133.30	0.50	3166.70	0.00
3266.70	-5.00	3333.30	-12.00	4333.30	-12.00
4666.70	0.00	4733.30	0.50	9266.70	0.50
9300.00	0.00	9400.00	-0.50	9600.00	-12.00
9733.30	-18.00	10000.00	-35.00	10333.30	-18.00
10466.70	-12.00	10600.00	0.00	10666.70	0.50
13600.00	0.50	13666.70	0.00	14166.70	-12.00
14933.00	0.00	15000.00	0.50	15500.00	0.50
15533.30	0.00	15666.70	-6.00	15866.70	-13.00

16233.30	-0.50	16333.30	0.00	16400.00	0.50
25166.60	0.50				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250					

E.1 Node Number of Elev Pts

25 16

E.2 Stations and Elevations

0.00	4.00	2600.00	0.00	2900.00	-0.50
3100.00	-6.00	3200.00	-12.00	3333.30	-18.00
5000.00	-33.00	6666.70	-42.00	7666.70	-36.00
8000.00	-24.00	8033.30	-18.00	8066.70	-12.00
8100.00	-6.00	8133.30	-0.50	8566.70	0.00
10000.00	4.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250		

E.1 Node Number of Elev Pts

26 28

E.2 Stations and Elevations

0.00	4.00	2266.70	0.00	2433.30	-0.50
2600.00	-42.00	3333.30	-48.00	4500.00	-27.00
4600.00	-18.00	4666.70	-12.00	4833.30	-6.00
5666.70	-12.00	6000.00	-12.00	6600.00	-6.00
6733.30	-6.00	7000.00	-8.00	7800.00	-12.00
8000.00	-17.00	8333.30	-12.00	8433.30	-6.00
9200.00	-0.50	10400.00	0.00	10500.00	0.50
13833.30	0.50	13866.70	0.00	14000.00	-6.00
14166.70	-7.00	14500.00	-6.00	14666.70	0.00
14733.30	0.50				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250		

E.1 Node Number of Elev Pts

27 26

E.2 Stations and Elevations

0.00	4.00	1933.30	0.50	4500.00	0.50
4533.30	0.00	4700.00	-0.50	5166.70	-6.00
5366.70	-12.00	5466.70	-18.00	5666.70	-22.00
6666.70	-30.00	8166.70	-24.00	8666.70	-18.00

8800.00	-6.00	9066.70	-0.50	9300.00	-0.50
9333.30	-1.00	10500.00	-6.00	11666.70	-13.00
12066.70	-6.00	12566.70	-0.50	12666.70	0.00
13000.00	0.50	13066.70	-9.00	13133.30	0.00
13333.30	0.50	23333.30	0.50		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

28 26

E.2 Stations and Elevations

0.00	0.50	6300.00	0.50	6333.30	0.00
6666.70	-20.00	6933.30	0.00	7000.00	0.50
8266.70	0.50	8333.30	0.00	8400.00	-0.50
9166.70	-20.00	10000.00	-20.00	10400.00	-18.00
11733.30	-18.00	12333.30	-21.00	13333.30	-32.00
13933.30	-18.00	14200.00	-12.00	14400.00	-6.00
14666.70	-5.00	14866.70	-6.00	15333.30	-19.00
15866.70	-6.00	16433.30	-0.50	16666.70	0.00
17333.30	0.50	20000.00	0.50		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

29 31

E.2 Stations and Elevations

0.00	0.50	3866.70	0.50	3933.30	0.00
4166.70	-6.00	4266.70	0.00	4333.30	0.50
5933.30	0.50	6000.00	0.00	7000.00	-0.50
8933.30	-6.00	9600.00	-6.00	10000.00	-12.00
10333.30	-14.00	10933.30	-12.00	11166.70	-10.00
12033.30	-12.00	13000.00	-24.00	13333.30	-32.00
13666.70	-25.00	14600.00	-18.00	14633.00	-12.00
15266.70	-12.00	15666.70	-0.50	15933.30	0.00
16000.00	0.50	16600.00	0.50	16666.70	0.00
18400.00	-9.00	18500.00	0.00	18666.60	0.50
20000.00	0.50				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250

0.0250 0.0250 0.0250 0.0250 0.0250 0.0250
0.0250

E.1 Node Number of Elev Pts
30 23

E.2 Stations and Elevations

0.00	0.50	2166.70	0.50	2500.00	4.00
2800.00	0.50	7000.00	0.50	7166.70	0.00
7600.00	-0.50	8333.30	-3.00	10000.00	-6.00
10400.00	-12.00	10666.70	-19.00	11733.30	-18.00
12333.30	-25.00	13166.70	-27.00	13333.30	-32.00
13600.00	-23.00	14000.00	-18.00	14166.70	-12.00
14333.30	-6.00	14400.00	-0.50	14833.30	0.00
14933.30	0.50	20000.00	0.50		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	

E.1 Node Number of Elev Pts
31 21

E.2 Stations and Elevations

0.00	0.50	666.70	4.00	1066.70	0.50
4000.00	0.50	4033.30	0.00	4166.70	-13.00
4400.00	0.00	4433.30	0.50	4933.30	0.50
5000.00	0.00	6133.30	-6.00	6333.30	-12.00
6666.70	-18.00	8133.30	-25.00	8333.30	-32.00
8600.00	-23.00	9200.00	-18.00	9266.70	0.00
9500.00	2.00	9733.30	0.50	16666.70	0.50

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250			

E.1 Node Number of Elev Pts
32 23

E.2 Stations and Elevations

0.00	0.50	533.30	4.00	1066.70	0.50
4533.30	0.50	5133.30	-6.00	5200.00	-12.00
5533.30	-18.00	6466.70	-21.00	6666.70	-32.00
6933.30	-22.00	7500.00	-20.00	7866.70	-18.00
8133.30	-6.00	8733.30	-0.50	8833.30	0.00
9166.70	2.00	9400.00	0.50	9666.70	0.50
9700.00	0.00	9733.30	-1.50	9800.00	0.00
9833.30	0.50	16666.70	0.50		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250

0.0250 0.0250 0.0250 0.0250 0.0250

E.1 Node Number of Elev Pts

33 25

E.2 Stations and Elevations

38000.00	0.00	38060.00	-27.00	38072.00	-32.00
38260.00	-29.00	38272.00	-29.00	38361.00	-32.00
38373.00	-32.00	38511.00	-30.00	38523.00	-30.00
38662.00	-33.00	38675.00	-33.00	38956.00	-37.00
38968.00	-37.00	39137.00	-38.00	39149.00	-38.00
39287.00	-35.00	39299.00	-35.00	39439.00	-32.00
39451.00	-32.00	39588.00	-32.00	39600.00	-32.00
39740.00	-23.00	40347.00	-20.00	40562.00	-23.00
40776.00	-2.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250					

E.1 Node Number of Elev Pts

34 45

E.2 Stations and Elevations

38000.00	0.00	38060.00	-27.00	38061.00	20.00
38071.00	20.00	38072.00	-27.00	38260.00	-26.00
38261.00	20.00	38271.00	20.00	38272.00	-26.00
38361.00	-30.00	38362.00	20.00	38372.00	20.00
38373.00	-30.00	38511.00	-28.00	38512.00	20.00
38522.00	20.00	38523.00	-28.00	38662.00	-33.00
38663.00	20.00	38673.00	20.00	38674.00	-33.00
38956.00	-35.00	38957.00	20.00	38967.00	20.00
38968.00	-35.00	39137.00	-35.00	39138.00	20.00
39148.00	20.00	39149.00	-35.00	39287.00	-36.00
39288.00	20.00	39298.00	20.00	39299.00	-36.00
39439.00	-31.00	39440.00	20.00	39450.00	20.00
39451.00	-31.00	39588.00	-30.00	39589.00	20.00
39599.00	20.00	39600.00	-30.00	39740.00	-27.00
40347.00	-22.00	40562.00	-20.00	40776.00	-2.00

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250			

E.1 Node Number of Elev Pts

35 45

E.2 Stations and Elevations

38000.00	0.00	38060.00	-27.00	38061.00	20.00
38071.00	20.00	38072.00	-32.00	38260.00	-29.00
38261.00	20.00	38271.00	20.00	38272.00	-29.00
38361.00	-32.00	38362.00	20.00	38372.00	20.00
38373.00	-32.00	38511.00	-30.00	38512.00	20.00
38522.00	20.00	38523.00	-30.00	38662.00	-33.00
38663.00	20.00	38673.00	20.00	38675.00	-33.00
38956.00	-37.00	38957.00	20.00	38967.00	20.00
38968.00	-37.00	39137.00	-38.00	39138.00	20.00
39148.00	20.00	39149.00	-38.00	39287.00	-35.00
39288.00	20.00	39298.00	20.00	39299.00	-35.00
39439.00	-32.00	39440.00	20.00	39450.00	20.00
39451.00	-32.00	39588.00	-32.00	39589.00	20.00
39599.00	20.00	39600.00	-32.00	39740.00	-32.00
40347.00	-23.00	40562.00	-20.00	40776.00	-23.00

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250			

E.1 Node Number of Elev Pts

36 24

E.2 Stations and Elevations

38000.00	0.00	38060.00	-30.00	38072.00	-30.00
38260.00	-30.00	38272.00	-30.00	38361.00	-31.00
38373.00	-31.00	38511.00	-33.00		
38523.00	-33.00	38662.00	-29.00	38675.00	-29.00
38956.00	-34.00	38968.00	-34.00	39137.00	-35.00
39149.00	-35.00	39287.00	-33.00	39299.00	-33.00
39439.00	-29.00	39451.00	-29.00	39588.00	-28.00
39600.00	-28.00	39740.00	-23.00	40347.00	-22.00
40562.00	-2.0				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250

E.1 Node Number of Elev Pts

37 16

E.2 Stations and Elevations

0.00	4.00	200.00	0.50	2200.00	0.50
2233.30	0.00	3833.30	-6.00	3933.30	-12.00
4066.70	-18.00	4833.30	-21.00	5000.00	-32.00

5400.00	-26.00	6100.00	-18.00	6333.30	-17.00
6666.00	-12.00	7133.30	-6.00	7433.30	0.00
7666.70	4.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250		

E.1 Node Number of Elev Pts

38 26

E.2 Stations and Elevations

0.00	0.50	1000.00	0.50	1233.30	4.00
1333.30	0.50	4966.70	0.50	5000.00	0.00
5066.70	-6.00	5200.00	-12.00	5933.30	-18.00
6466.70	-19.00	6666.70	-32.00	6800.30	-21.00
7466.70	-18.00	7533.30	-12.00	7566.70	-6.00
7733.30	0.00	7933.30	-6.00	7966.70	-12.00
8166.70	-18.00	8333.30	-21.00	8466.70	-18.00
9066.00	-12.00	9333.30	-18.00	9666.70	-27.00
11000.70	-18.00	11033.00	4.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

39 25

E.2 Stations and Elevations

0.00	1.00	600.00	4.00	833.30	0.50
4933.30	0.50	5000.00	0.00	5066.70	-6.00
5133.30	-12.00	5600.00	-18.00	6466.70	-25.00
6666.70	-32.00	6800.00	-29.00	7466.70	-18.00
7666.70	-12.00	7833.30	-6.00	7966.70	-0.50
8533.30	0.00	9000.00	4.00	14333.30	4.00
15333.30	0.00	15366.70	-12.00	15400.00	-18.00
15666.70	-27.00	15700.00	-14.00	15866.70	0.00
17333.30	4.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250					

E.1 Node Number of Elev Pts

40 22

E.2 Stations and Elevations

0.00	4.00	1066.70	0.50	6000.00	0.50
6033.30	0.00	6166.70	-6.00	6266.70	-12.00

6500.00	-22.00	6666.70	-32.00	6933.30	-31.00
8100.00	-18.00	8300.00	-12.00	8333.30	-6.00
8366.70	-0.50	8433.30	0.00	9000.00	4.00
5166.70	4.00	15900.00	0.00	15933.30	-25.00
16166.70	-27.00	16400.00	-25.00	16633.30	0.00
16666.70	4.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250		

E.1 Node Number of Elev Pts

41 37

E.2 Stations and Elevations

0.00	0.50	1000.00	0.50	1666.70	0.00
2166.70	-3.00	2333.30	0.00	2366.70	0.50
4600.00	0.50	4666.70	0.00	5000.00	-2.00
5500.00	-0.50	5866.70	-6.00	5933.30	-12.00
6200.00	-18.00	6266.70	-20.00	6333.30	-18.00
6366.70	0.00	6400.00	0.50	9066.70	0.50
9266.70	-0.50	9333.30	-6.00	9833.30	-20.00
10000.00	-32.00	10233.30	-22.00	11333.30	-18.00
11566.70	-12.00	11666.70	-6.00	11800.00	-0.50
12066.70	-0.50	13000.00	-3.00	13666.70	-1.00
15833.30	0.00	16000.00	0.50	19666.60	0.50
19700.00	0.00	19833.30	-20.00	20166.60	0.00
20333.30	4.00				

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250					

E.1 Node Number of Elev Pts

42 38

E.2 Stations and Elevations

0.00	0.50	2733.30	0.50	2766.70	0.00
3000.00	-9.00	3133.30	0.00	3166.70	0.50
5666.70	0.50	5700.00	0.00	5833.30	-6.00
5933.30	-18.00	6000.00	-6.00	6066.70	0.00
7533.30	0.50	7900.00	4.00	13600.00	0.50
14400.00	-0.50	15000.00	-12.00	15266.70	-16.00
15400.00	-12.00	15733.30	-6.00	15833.30	-2.00
15933.30	-6.00	16266.70	-18.00	16500.00	-21.00
16666.70	-32.00	16833.30	-21.00	17400.00	-18.00
17500.00	0.00	17533.30	0.50	21533.30	0.00
21666.60	-6.00	21900.00	0.00	21933.30	0.50
22866.60	0.00	23200.00	-6.00	23266.60	0.00
23333.30	0.50	23666.60	4.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

E.1 Node Number of Elev Pts

43 38

E.2 Stations and Elevations

0.00	0.50	2733.30	0.50	2766.70	0.00
3000.00	-9.00	3133.30	0.00	3166.70	0.50
5666.70	0.50	5700.00	0.00	5833.30	-6.00
5933.30	-18.00	6000.00	-6.00	6066.70	0.00
7533.30	0.50	7900.00	4.00	13600.00	0.50
14400.00	-0.50	15000.00	-12.00	15266.70	-16.00
15400.00	-12.00	15733.30	-6.00	15833.30	-2.00
15933.30	-6.00	16266.70	-18.00	16500.00	-21.00
16666.70	-32.00	16833.30	-21.00	17400.00	-18.00
17500.00	0.00	17533.30	0.50	21533.30	0.00
21666.60	-6.00	21900.00	0.00	21933.30	0.50
22866.60	0.00	23200.00	-6.00	23266.60	0.00
23333.3C	0.50	23666.60	4.00		

E.3 Mannings Coefficient at each station

0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250	0.0250	0.0250	0.0250	0.0250
0.0250	0.0250				

EXTER.DAT file

```
**************************************************
F    Time-Dependent Data
**************************************************
```

F.1 Index	Time	Node 1	Node 25	Node 43
1	5.00	5.00	0.00	0.00
2	5.50	5.80	0.00	0.00
3	6.00	7.00	0.00	0.00
4	6.50	7.50	0.00	0.00
5	7.00	8.00	0.00	0.00
6	7.50	8.50	0.00	0.00
7	8.00	8.75	0.00	0.00
8	8.50	8.80	0.00	0.00
9	9.00	9.00	0.00	0.00
10	9.50	8.75	0.00	0.00
11	10.00	8.00	0.00	0.00
12	10.50	7.50	0.00	0.00
13	11.00	6.00	0.00	0.00
14	12.50	3.50	0.00	0.00
15	13.50	1.50	0.00	0.00
16	14.00	0.20	0.00	0.00
17	14.50	0.15	0.00	0.00
18	15.00	0.10	0.00	0.00
19	15.50	0.15	0.00	0.00
20	16.00	1.50	0.00	0.00
21	17.50	4.50	0.00	0.00
22	18.00	6.00	0.00	0.00
23	18.50	7.00	0.00	0.00
24	19.00	8.00	0.00	0.00
25	19.50	8.50	0.00	0.00
26	20.00	8.75	0.00	0.00
27	20.50	8.80	0.00	0.00
28	21.00	9.00	0.00	0.00
29	21.50	8.75	0.00	0.00
30	22.00	8.00	0.00	0.00
32	22.50	7.50	0.00	0.00
33	23.00	6.00	0.00	0.00
34	24.50	3.50	0.00	0.00
35	25.50	1.50	0.00	0.00

PARAM.DAT Input Data File for DYNLET Graphs

G.1 Number of Nodes at which velocity plots are desired:
1
G.2 Node Number for Velocity Plot:
35
G.3 Number of Velocity Stations at this Node =
4
G.4 The Velocity Stations are:
11 12 13 14
H.1 Number of Nodes for Stage Graphs =
13
H.2 The Stage Graph Nodes are:
1 2 3 4 5 6 22 23
33 34 35 36 38

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13. ABSTRACT *(Maximum 200 words)*

This study was sponsored by the U.S. Department of Transportation (DOT) whose primary interest is in the development of a statistical approach for estimating frequency-indexed currents impacting bridge piers at project sites. Model DYNLET1 is used to compute the storm-induced velocities near bridge piers. DYNLET1 is a one-dimensional (1-D), shallow-water equation, hydrodynamic model for predicting velocities and water level fluctuations in a system of inlets and bays (Amein and Kraus 1991, 1992). An important feature of the model is the ability to accurately represent flow distribution across any cross section, given the inherent limitations of a 1-D model.

This report describes the process of applying DYNLET1 to a tidal inlet, specifically to Brunswick Harbor, Georgia, for the purpose of estimating tide and storm response at U.S. Department of Transportation (DOT) project sites.

14. SUBJECT TERMS
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